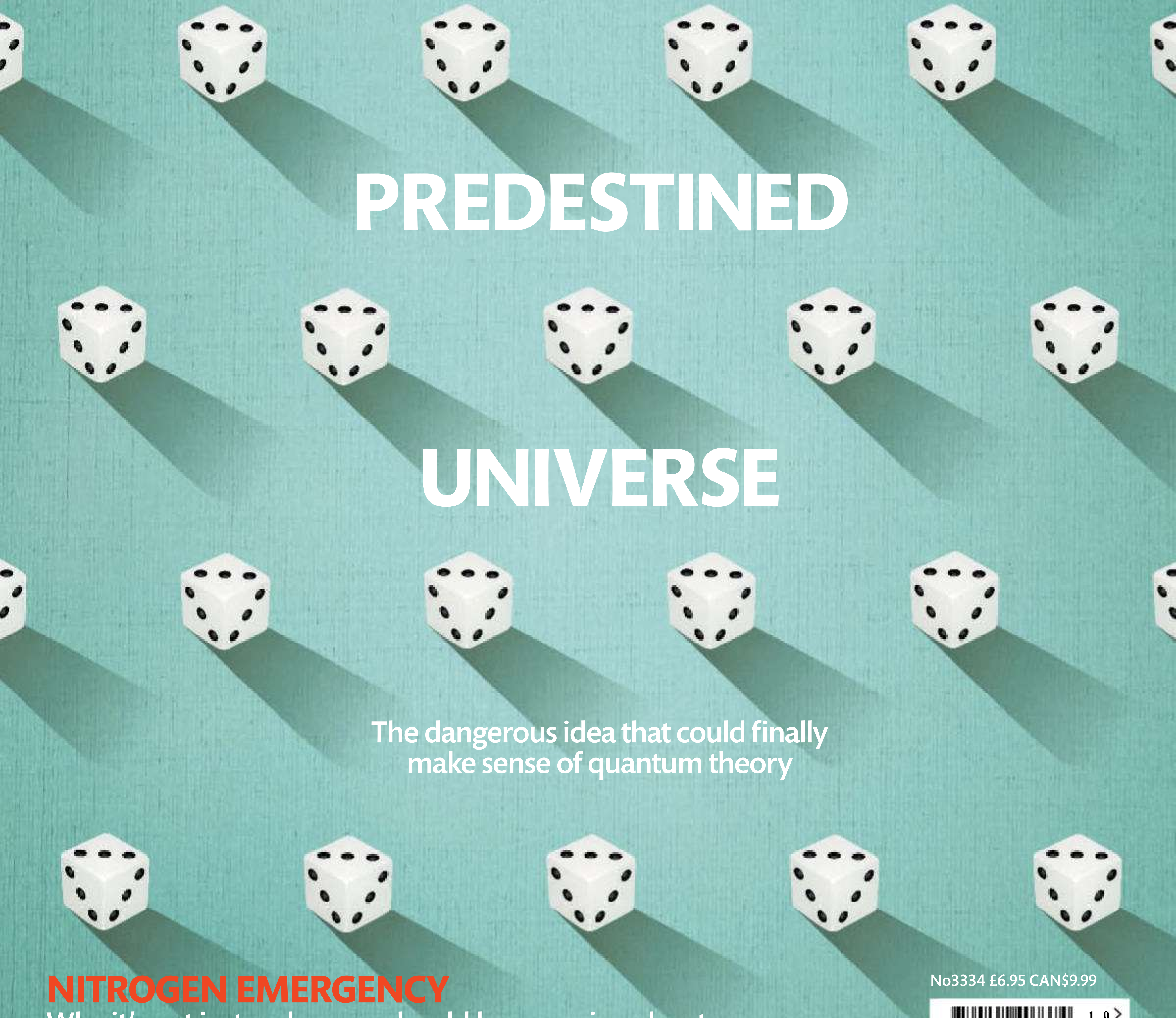
New Scientist

WEEKLY 15 May 2021

TRUTH ABOUT JET LAG
Is it really all in your mind?

COVID-19 BOOSTERS
What we know so far

FEELING THE WORLD
Your brain's amazing ability to create new senses



PREDESTINED UNIVERSE

The dangerous idea that could finally make sense of quantum theory

NITROGEN EMERGENCY
Why it's not just carbon we should be worrying about

PLUS KITES ON MARS / **A GREENER BITCOIN?** / THE CERNE GIANT / **EPIC V APPLE** / THE INDIAN VARIANT / **WHY ISN'T TIME DECIMAL?**

No3334 £6.95 CAN$9.99

SUSTAIN.
ABILITY.

JUPITER GLOBAL SUSTAINABLE EQUITIES FUND

Transformational businesses, with the right mindset and imagination, can lead the transition to a more sustainable world economy. With over three decades of combined ESG investment experience, our global sustainable equities team believes that companies that balance the interests of the planet, people and profit are the most sustainable in the long term. We have dedicated our careers to identifying businesses with a demonstrable commitment to supporting this transition to a brighter future. We call this human advantage 'the value of active minds'. Visit **jupiteram.com**

As with all investing, your capital is at risk.

JUPITER
ASSET MANAGEMENT

This advert is for informational purposes only and is not investment advice. We recommend you discuss any investment decisions with a financial adviser, particularly if you are unsure whether an investment is suitable. The Key Investor Information Document, Supplementary Information Document and Scheme Particulars are available from Jupiter on request. Jupiter Unit Trust Managers Limited, registered address: The Zig Zag Building, 70 Victoria Street, London SW1E 6SQ is authorised and regulated by the Financial Conduct Authority. JAM001957-002-0421

This week's issue

On the cover

36 Predestined universe
The dangerous idea that could finally make sense of quantum theory

41 Nitrogen emergency
Why it's not just carbon we should be worrying about

Vol 250 No 3334
Cover image: Julie Lee

16 Truth about jet lag
Is it really all in your mind?

8 Covid-19 boosters
What we know so far

46 Feeling the world
Your brain's amazing ability to create new senses

17 Kites on Mars 13 A greener bitcoin? 14 The Cerne Giant 23 Epic v Apple 7 The Indian variant 54 Why isn't time decimal?

46 Features

> **"What you find in the brain is a system of such complexity that it bankrupts language"**

News

12 Evolution of childbirth
We are rethinking the idea that risky birth is uniquely human

15 Stop the clocks
Measuring time increases the entropy of the universe

17 Social media society
Why Facebook's "Supreme Court" won't rein in Donald Trump

Views

23 Comment
Frederike Kaltheuner on the court case between Apple and Epic Games

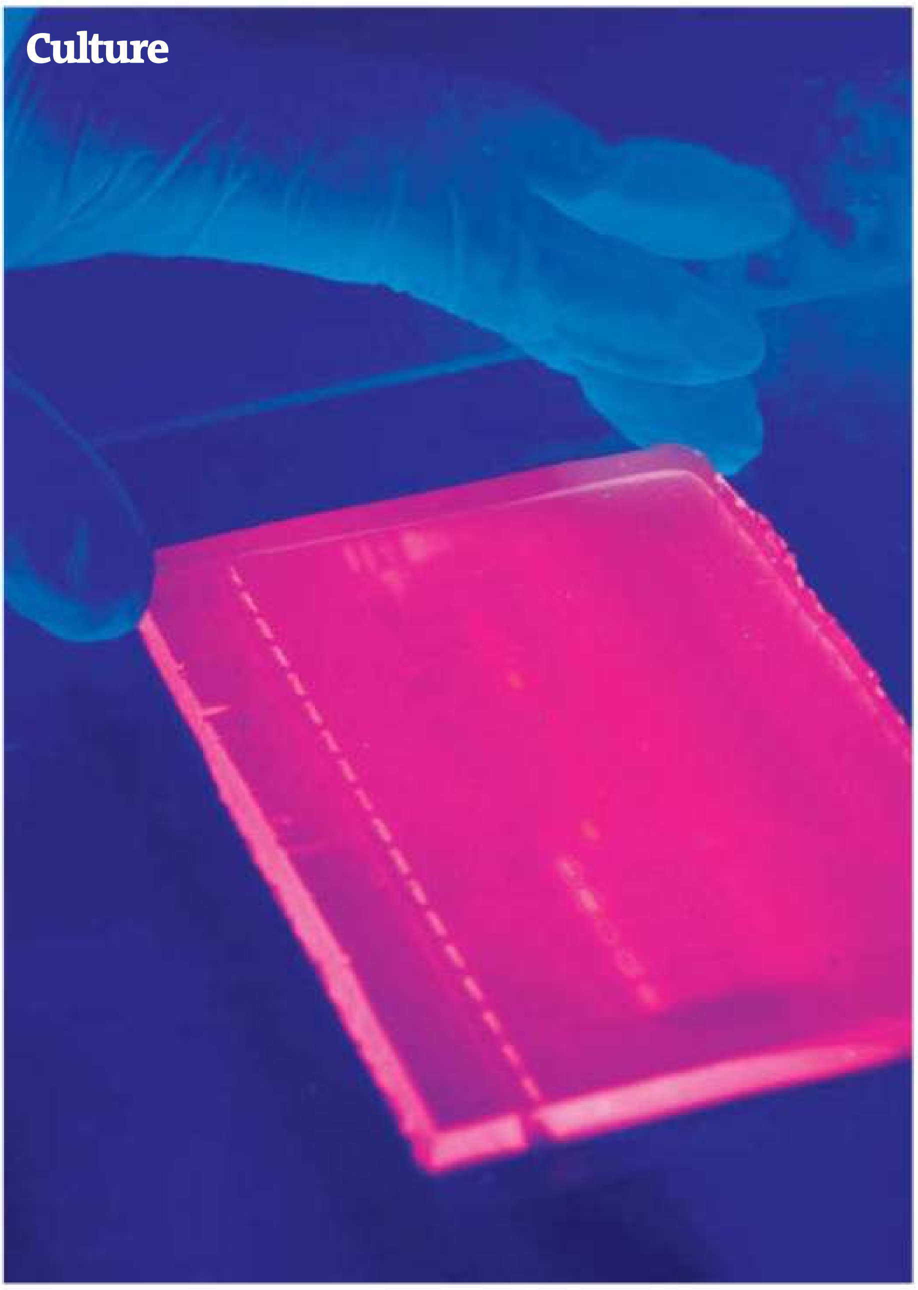
24 The columnist
A new era of robots is coming, writes Annalee Newitz

26 Letters
Bend the ear of politicians to tackle the climate crisis

28 Aperture
The Amazon and its people

34 Culture columnist
Clare Wilson on a compelling new space opera

Culture



PIDJOE/GETTY IMAGES

32 Life after Earth An ambitious book sets out a plan for humanity

Features

36 Predetermined universe?
The idea that the quantum world isn't random might finally make sense of quantum theory

41 The godfather of pollution
Nitrogen is fouling our planet with terrible effects. Now we are organising a global clean up

46 David Eagleman interview
How our brains can learn to experience new senses

The back pages

51 Stargazing at home
How to spot Leo and Virgo

52 Puzzles
Try our crossword, quick quiz and logic puzzle

54 *Almost* the last word
Why has time never been decimalised? Readers respond

55 Tom Gauld for *New Scientist*
A cartoonist's take on the world

56 Feedback
Martian mushrooms and free pigeon trips: the week in weird

Elsewhere on New Scientist

Virtual event

The future of healthcare

The coronavirus pandemic has put the spotlight on human health like never before. In this one-day event, we will hear from 15 fantastic speakers about what the future of healthcare will look like, covering everything from long covid to regenerative medicine and robot surgery to gut health. There will be plenty of time for live audience questions too. Join us on 26 June from 10am to 5pm BST or watch on demand later. Tickets available now.

newscientist.com/events

Podcast

Weekly

The team is joined by climate scientist Tamsin Edwards, who has published a crucial analysis of what climate change beyond a 1.5°C rise will look like. Plus: the science of self-reflection, the climate impact of Bitcoin and the first species of ant with a gender-neutral name.

newscientist.com/podcasts

Online

Covid-19 daily briefing

All the most important developments in the pandemic in one essential briefing. Updated daily at 6pm BST.

newscientist.com/coronavirus-latest

Explosive stuff Sam Wong explores volcanoes on other worlds

ANNIKA BRANDOW

Say cheese! Climate change takes centre stage in a new video game

Newsletter

Fix the Planet

Get a weekly dose of climate optimism delivered free to your inbox. This week, reporter Adam Vaughan looks at *Survive the Century*, one of the few video games that directly tackles climate change.

newscientist.com/sign-up/fix-the-planet

Video

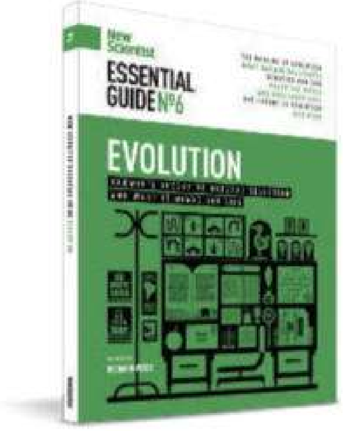
Science with Sam

From ice eruptions on Saturn's moons to lava on asteroids, volcanoes are found throughout the solar system. This week, Sam takes a tour of them and explains why they could be a key factor in making other worlds habitable. Subscribe online to never miss an episode.

youtube.com/newscientist

Newsletter

> **"Climate change has captured the zeitgeist of modern fiction. But in gaming, it can feel like it barely exists"**



Essential guide

Get to grips with all the grandeur and complexity of Charles Darwin's peerless theory of natural selection with our *Essential Guide: Evolution*, the sixth in the series. Available to purchase now.

shop.newscientist.com

SCOTTISH
MORTGAGE
INVESTMENT
TRUST

We seek out lateral thinkers to shape our investment ideas.

Not the usual suspects.

We ignore many opinions produced by the narrow mindset of financial analysts and investment industry commentators. Instead we look to academia, to authors, to experts in industry, to people who think differently. In this way **Scottish Mortgage Investment Trust** can continue to build a portfolio that reflects real-world progress, not financial-world noise.

Please remember that changing stock market conditions and currency exchange rates will affect the value of the investment in the fund and any income from it. Investors may not get back the amount invested.

Find out more by watching our film at scottishmortgageit.com
A Key Information Document is available. Call 0800 917 2112.

BAILLIE GIFFORD | *Actual Investors*

Your call may be recorded for training or monitoring purposes. Issued and approved by Baillie Gifford & Co Limited, whose registered address is at Calton Square, 1 Greenside Row, Edinburgh, EH1 3AN, United Kingdom. Baillie Gifford & Co Limited is the authorised Alternative Investment Fund Manager and Company Secretary of the Trust. Baillie Gifford & Co Limited is authorised and regulated by the Financial Conduct Authority. The investment trusts managed by Baillie Gifford & Co Limited are listed UK companies and are not authorised and regulated by the Financial Conduct Authority.

Introducing DaVinci Resolve 17

Edit and color correct video with the same software used by Hollywood, for free!

DaVinci Resolve 17 is a major new update packed with over 300 features and enhancements! Colorists get new HDR grading tools, AI based magic mask, color warper and more. Fairlight adds lightning fast keyboard and mouse sound editing tools. Editors get new metadata 'slate' view, smart reframing, proxies, keying, Fusion effects and more!

Next Generation HDR and Color Features!

New HDR grading tools, redesigned primary controls, AI based magic mask and more. The new HDR palette lets you create custom color wheels for targeted corrections, magic mask uses the DaVinci Neural Engine to isolate and track objects, and the color warper lets you morph colors in creative new ways! New DaVinci wide gamut image processing gives you even higher quality!

World's Fastest and Highest Quality Pro Audio Tools!

Fairlight features a powerful new engine that supports up to 2,000 realtime tracks with effects, dynamic and EQ. The new context sensitive edit selection tools and updated shortcuts make it even faster and easier to use, especially if you're switching from another system. You can now reverse clips, analyze loudness, view transients, preview video, move automation and more!

Powerful New Edit and Cut Page Features!

A new metadata 'slate' view with bin dividers makes it easy to sort and find clips based on scene, shot, camera, and more! There's also new audio trimming on the cut page, AI based smart reframing for changing aspect ratio, a new portable proxy workflow that supercharges edit performance, render in place, timeline based syncing, compositing, keying, Fusion effects and more!

Fusion Effects, Titles and Transitions for Editors!

DaVinci Resolve 17 lets you save anything created on the Fusion page as an effect, title or transition that can be used on the edit and cut pages! New animation curve modifiers automatically retime animations when clip length is changed, there are new vector shape tools for motion graphics, shared markers, and audio playback with graphical waveform!

DaVinci Resolve .... **Free**

DaVinci Resolve Studio... **US$295**

Free DaVinci Resolve Speed Editor with purchase of DaVinci Resolve Studio

Learn more at www.blackmagicdesign.com

Available for Mac, Windows and Linux

In need of a fix

Nitrogen pollution has long ravaged the environment. It is time for a clean-up

CARBON is in the news a lot these days. Story after horrifying story tells of how carbon emissions are turning up Earth's thermostat with dire consequences. But when it comes to the environment, there is another element we need to worry about. Nitrogen, carbon's next-door neighbour on the periodic table, is at the centre of a different environmental crisis that is rarely in the limelight.

Like so much in life, nitrogen is good in moderation. It is the fourth most common element in your body, an essential ingredient of DNA and other crucial biomolecules. We get this nitrogen from the food we eat. To enter the food chain, the relatively inert nitrogen gas in the air has to be converted, or fixed, to "reactive nitrogen" compounds in the soil, which are taken up by plants. Over the past century, we've added to the natural processes that do this by producing synthetic fertiliser in huge quantities and slathering it on fields. The average person in the US has a nitrogen footprint of about 41 kilograms per year, mostly thanks to the fertiliser used to grow their food.

> "The seemingly different environmental catastrophes we are facing are intertwined"

A lot of reactive nitrogen ends up leaching into the wider environment where it disrupts the natural chemical balance. We have known this for decades. Back in 1996, *New Scientist* was reporting on how nitrogen run-off causes blooms of toxic algae – "red tides" – that kill sea life. The long list of effects includes air pollution, acid rain and soil acidification.

Finally, it seems the world might be confronting the problem. A UN-backed group called the International Nitrogen Management System is beginning to chart a well-evidenced course out of the nitrogen emergency. It has helped set a target of cutting nitrogen waste in half by 2030 and put forward a range of ways to pull this off (see page 41).

It is a welcome start. But we shouldn't forget that the seemingly different environmental catastrophes we are facing, not least biodiversity decline and climate change, are intertwined and mutually reinforcing. This is true of nitrogen too: one nitrogen pollutant, nitrous oxide, is a greenhouse gas that is 300 times more potent than carbon dioxide. We need to hear a lot more about nitrogen. ▮

PUBLISHING & COMMERCIAL

Commercial and events director Adrian Newton
Display advertising
Tel +44 (0)20 7611 1291 **Email** displayads@newscientist.com
Sales director Justin Viljoen
Sales manager Rosie Bolam
Recruitment advertising
Tel +44 (0)20 7611 1204 **Email** nssales@newscientist.com
Recruitment sales manager Viren Vadgama
New Scientist Events
Tel +44 (0)20 7611 1245 **Email** live@newscientist.com
Creative director Valerie Jamieson
Sales director Jacqui McCarron
Event manager Henry Gomm
Marketing manager Emiley Partington
Events team support manager Rose Garton
New Scientist Discovery Tours
Director Kevin Currie
Marketing
Marketing director Jo Adams
Head of campaign marketing James Nicholson
Head of customer experience Emma Robinson
Email/CRM manager Rose Broomes
Digital marketing manager Craig Walker
Customer experience marketing manager Esha Bhabuta
Marketing executive Amelia Parmiter
Digital & Data
Digital product development director Laurence Taylor
Head of audience data Rachael Dunderdale
Business intelligence analyst Michael Prosser
Technology
CTO and programme director Debora Brooksbank-Taylor
Head of technology Tom McQuillan
Maria Moreno Garrido, Dan Pudsey, Amardeep Sian,
Ben Townsend, Piotr Walków

NewScientist

Chief executive Nina Wright
Executive assistant Lorraine Lodge
Finance & operations
Chief financial officer Amee Dixon
Financial controller Taryn Skorjenko
Management Accountant Alfred Princewill
Facilities manager Ricci Welch
Receptionist Alice Catling
Human resources
Human resources director Shirley Spencer
HR business partner Katy Le Poidevin

CONTACT US

newscientist.com/contact
General & media enquiries
UK **Tel**+44 (0)20 7611 1200
25 Bedford Street, London WC2E 9ES
Australia 418A Elizabeth St, Surry Hills, NSW 2010
US PO Box 80247, Portland, OR 97280
UK Newsstand
Marketforce UK Ltd **Tel** +44 (0)33 0390 6555
Syndication
Tribune Content Agency **Tel** +44 (0)20 7588 7588
Email tca-articlesales@tribpub.com
Subscriptions
newscientist.com/subscription
One year print subscription (51 issues) UK £198
Tel +44 (0)330 333 9470
Email subscriptions@newscientist.com
Post New Scientist, Rockwood House, Perrymount Road,
Haywards Heath, West Sussex RH16 3DH

© 2021 New Scientist Ltd, England.
New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Precision Colour Printing Ltd

EDITORIAL

Editor Emily Wilson
Executive editor Richard Webb
Creative director Craig Mackie
News
News editor Penny Sarchet
Editors Jacob Aron, Helen Thomson, Chelsea Whyte
Reporters (UK) Jessica Hamzelou, Michael Le Page,
Layal Liverpool, Matthew Sparkes,
Adam Vaughan, Clare Wilson
(US) Leah Crane, (Aus) Alice Klein, Donna Lu
Interns Ibrahim Sawal, Karina Shah, Krista Charles
Digital
Digital editor Conrad Quilty-Harper
Podcast editor Rowan Hooper
Web team Emily Bates, Anne Marie Conlon, Matt Hambly,
Alexander McNamara, David Stock, Sam Wong
Features
Head of features Catherine de Lange
and Tiffany O'Callaghan
Editors Daniel Cossins, Anna Demming,
Kate Douglas, Alison George, Joshua Howgego
Feature writer Graham Lawton
Culture and Community
Comment and culture editor Timothy Revell
Liz Else
Subeditors
Chief subeditor Eleanor Parsons
Bethan Ackerley, Tom Campbell,
Chris Simms, Jon White
Design
Art editor Julia Lee
Joe Hetzel, Ryan Wills
Picture desk
Picture editor Helen Benians
Tim Boddy
Production
Production manager Joanne Keogh
Robin Burton

recycle

New Scientist Academy

LAUNCHING JUNE 2021

ONLINE COURSES TO ENLIGHTEN, ENTERTAIN AND INSPIRE

COURSE THREE

YOUR IMMUNE SYSTEM AND HOW TO BOOST IT

Understanding the immune system has never been so important. This course is a vital primer on the biology of the immune system, how it works, when it changes and what you can do to keep it healthy. From covid-19 to the common cold, the course will give you the lowdown on how your body works to protect you and the actions you can take to help.

COURSE OVERVIEW:

- Why your immune system matters
- How the immune system works
- How it changes during the course of your life
- The principles of vaccination
- Supporting your immune system

INCLUDED IN THIS COURSE:

- EXPERT LED VIDEO TUTORIALS
- EXPLAINER VIDEOS, INTERACTIVE DIAGRAMS, QUIZZES AND MORE
- ACCESS TO PREMIUM *NEW SCIENTIST* RESOURCES
- CPD ACCREDITED CERTIFICATE
- COMMUNITY AND DISCUSSION GROUPS
- LEARN AT YOUR OWN PACE: 6-10 HOURS OF LEARNING

Pre-order now and save £100*. Find out more at
newscientist.com/immune-course

*£100 saving is off the standard rate.

SUMIT DAYAL/BLOOMBERG VIA GETTY IMAGES

A relative watches a covid-19 patient in Ghaziabad, India, being given oxygen

Transmission

Worries over India variant

Health bodies are concerned about coronavirus variants coming from India that seem to be passed on more readily, reports **Adam Vaughan**

A FORM of the coronavirus variant first identified in India, which is now spreading in the UK, appears to be passed on at least as easily as the "Kent variant" that now dominates UK infections. The variant, called B.1.617.2, was designated a "variant of concern" on 7 May by health authorities in England.

B.1.617.2 is one of three sub-lineages of B.1.617, the variant that has become common in India and which some consider to be one potential factor behind the crisis that India has been facing. On 10 May, the World Health Organization designated B.1.617 as a variant of global concern.

Public Health England (PHE) has moderate confidence that the B.1.617.2 variant is on a par for transmissibility with B.1.1.7, also known as the Kent variant, which originated in the UK, said Sharon Peacock at the University of Cambridge at a press briefing on 10 May. The view is based on B.1.617.2's mutations and its ability to circulate in the UK alongside the Kent variant.

However, there is still much we don't know about the Indian variants.

Peacock said the moderate level of confidence was because we won't know how readily B.1.617.2 transmits until studies are done with more cases. "There's a huge amount of uncertainty around this at the moment," she said.

Encouragingly, the variant doesn't seem to be more harmful. "There isn't any evidence that this causes more severe disease," said Peacock, referring to data from the UK. She noted that the mortality rate has been high in India, but the country was operating in challenging circumstances, and there was no reason to think the variant caused covid-19 to be more severe.

The total number of confirmed cases of the variant in the UK stands at 520, with 318 of those between 28 April and 5 May. Mapping of cases that have been genetically sequenced suggests hotspots in central and north-west England, with the highest rates in Bolton. Being officially designated a variant of concern by PHE means surge testing is available to local areas to contain its spread in tandem with contact tracing.

Despite the classification of the variant, restrictions in England are due to ease on 17 May, including bars and restaurants allowing customers indoors, and small groups allowed to meet inside homes.

"There is a possibility the new variant becomes the UK's dominant form of the coronavirus"

Unlike the other two versions of the India variant, B.1.617.2 doesn't have the E484Q mutation which, like the E484K mutation, may be linked to helping the virus evade antibodies. For that reason, Peacock said the variant circulating in the UK "worries me less" than another version prevalent in India, B.1.617.1.

Ravi Gupta at the University of Cambridge said at the press briefing that research suggests B.1.617.1 does have a greater ability to bypass defences triggered by vaccination or an earlier coronavirus infection. He said there are signs it is better at spreading among vaccinated people, even though vaccination still appears to protect against severe disease. "In terms of controlling transmission, there may be a degree of compromise," he said.

There is a possibility the version in the UK, B.1.617.2, becomes the country's dominant form of the coronavirus, said Gupta. "It all depends on the dynamics of transmission and how quickly we can detect [variants] and close them off."

The good news is that old ways of limiting infection will work for B.1.617.2 and other new variants. "This isn't a special variant that is going to get around washing your hands, distancing, wearing a mask and being in a well-ventilated place," said Peacock. ▮

Daily coronavirus news round-up
Online every weekday at 6pm BST
newscientist.com/coronavirus-latest

Immunity

Are booster shots coming?

Vaccine top-ups might boost immune systems and block new coronavirus variants, but there are many unknowns, reports **Graham Lawton**

AS THE UK and some other wealthy countries edge towards a fully vaccinated adult population, a new question is being asked: will people need booster vaccines against covid-19?

The answer depends on three unknowns: how quickly immunity fades, whether current vaccines protect against existing and future coronavirus variants, and whether booster shots actually work. There are also issues of vaccine nationalism and equity to consider (see "Boost or bust?", right).

60m

Doses of vaccine ordered by the UK for possible booster campaign

Booster vaccines are routinely used for some infectious diseases, either to top up immunity or to update it for new virus variants. Tetanus boosters, for example, are recommended every 10 years to renew waning immunity, and annual flu shots are designed to protect against that season's variants.

Israel is ahead of the curve. The country has already vaccinated more than 80 per cent of over-16s and announced last month that it would run a booster campaign in October. Prime Minister Benjamin Netanyahu said in a televised address that Israel had secured 16 million extra doses of the Pfizer/BioNTech and Moderna vaccines to immunise its under-16s and boost everybody else.

Other countries whose immunisation programmes are progressing well are more circumspect. The UK is on course to have offered a first vaccine dose to its adult population by the end of July, and is now weighing up an autumn booster campaign. "We haven't made any decisions on this yet," says Anthony Harnden at the University of Oxford, deputy chair of the Joint Committee on Vaccination and Immunisation (JCVI), which advises UK health departments.

The UK has ordered a further 60 million doses of the Pfizer/BioNTech vaccine in preparation for a possible booster campaign but "we can't make the decision until we've seen all the evidence", says Harnden. It is possible that the JCVI will recommend a booster for the vulnerable groups that were first in line for a vaccine in the UK, he says. The JCVI will announce its decision as soon as it is made.

The US has also yet to make a call. A statement from the Centers for Disease Control and Prevention, which oversees the US vaccination programme, says: "The need for and timing for COVID-19 booster doses have not been established. No additional doses are recommended at this time."

The first piece of evidence needed is how quickly immunity fades after a vaccine. "I don't think we know, because we've not really got the data on what happens nine months after a [covid-19] vaccine," says virologist Deenan Pillay at University College London (UCL).

That information should be forthcoming soon, says Alex Richter, an immunologist at the University of Birmingham, UK. Various research projects on the duration of immunity in healthcare workers are due to report results over the next few weeks, she says. For example, the SIREN study, which is following more than 44,000 staff at 135 hospitals across the UK, is looking at the duration of immunity after having a Pfizer/BioNTech vaccine. The first vaccines were given in December and a six-month assessment is due out in June, says Richter. "If data at that point is showing significant waning [of antibodies], then that will influence policy," she says. "Most healthcare workers are really fit and healthy, so if they are not hanging onto their antibodies then it's highly likely we're going to need to be vaccinating in the autumn with a booster."

SASCHA STEINBACH/EPA-EFE/SHUTTERSTOCK

People receive a covid-19 vaccine in Cologne, Germany

DANIEL DAL ZENNARO/EPA-EFE/SHUTTERSTOCK

It might be best to give people a booster of a different vaccine

Another consideration is whether the current vaccines protect against viral variants. If they don't, then a booster campaign may be needed using shots tailored to protect against specific variants.

According to Harnden, lab studies show that vaccine-induced antibodies remain effective against the B.1.1.7 variant first seen in the UK and the P.1 variant from Brazil, but there are concerns about B.1.351, first identified in South Africa. "We do know that the vaccines are not quite as effective against the South African variant

Health Check newsletter
Get a weekly round-up of health news in your inbox
newscientist.com/healthcheck

in terms of preventing disease, although they do seem to be pretty good at preventing severe disease, hospitalisations and deaths," says Harnden.

If any variant proves capable of escaping the immunity conferred by current vaccines, then a variant-busting booster campaign is on the cards, he says.

Inadequate data

Right now, we don't know if vaccine escape is a genuine danger. "This is a critical question," says Pillay. "We really need a coherent assessment of the nature of breakthrough infections – in other words, infections that are happening in those who are fully immunised. Is that driven by variants, or is it to do with declining antibody and immunity from the first two doses [of vaccine]?"

A recent study documented two cases of breakthrough infections in a group of 417 fully vaccinated people, due to what seems to be a new variant (*NEJM*, doi.org/gjsbr9). "That is the level of data we've currently got, which is clearly inadequate to determine a major policy," says Pillay.

Despite the uncertainties, Israel has acted already on this too. It has negotiated an option to buy doses of Moderna's variant-specific booster vaccines, assuming they are approved. Moderna has two such booster vaccines in clinical trials. One is designed to protect against B.1.351, the other is a combination of this and the firm's original vaccine. Moderna is also testing booster shots of its initial vaccine and recently announced positive results from two of its trials. Pfizer is also testing booster shots of its first coronavirus vaccine and a variant-specific one.

Another factor to weigh up in relation to variants is an immunological phenomenon called original antigenic sin. This is where an updated vaccine reactivates an earlier immune memory rather than creating a new one. It has been seen with other viral infections including flu, says Anthony Costello at UCL, but whether it will be a problem with the virus that causes covid-19, SARS-CoV-2, remains to be seen. Studies to establish this are urgently needed, says John Moore at Weill Cornell Medicine in New York, because original antigenic sin could render a variant-specific booster campaign pointless.

Booster shots could fail for other reasons. A third dose of viral-vector vaccines like the Oxford/AstraZeneca one could just boost the immune response to the harmless virus used as a vehicle to deliver the active ingredient. "One of the concerns is that we may not be able to augment the antibodies against the [SARS-CoV-2] spike protein," says Teresa Lambe at the University of Oxford, who worked on the vaccine's development. She is doing experiments to determine the immune response to a third dose.

> "The idea that you can continually boost immunity is both logistically and immunologically difficult"

For this reason and others, it may be preferable to boost people's immunity with a different vaccine from the one they got the first two times.

There is some evidence that using different vaccines for the first and second dose – a method called heterologous prime-boost vaccination – produces a stronger immune response than using the same vaccine for both.

Russia's Sputnik V, for example, is a heterologous prime-boost vaccine and the latest real-world figures from the country show that it is 97.6 per cent effective, which would make it the most effective covid-19 vaccine in the world.

Ongoing experiments in the UK are examining the effects of mixing and matching first and second vaccine doses, and the results could inform decisions on a booster campaign, says Harnden.

All of these uncertainties emphasise an important point that has been largely forgotten amid vaccine euphoria, says Costello. "The idea that you can continually boost [immunity] is both logistically difficult and may be immunologically difficult." We may face breakthrough infections that can't be vaccinated against and so we will still need interventions such as masks, ventilation and social distancing. "Vaccination has been great, but it's not going to solve the problem in its entirety," says Costello. ▮

Boost or bust?

Rich countries like Israel and the UK are already buying up tens of millions of extra vaccine doses for potential immunity booster campaigns (see main story), but the strategy could end up making the covid-19 pandemic worse.

As the World Health Organization has repeatedly said, the pandemic can't end until the whole world is vaccinated.

Unvaccinated populations could act as a source of yet more new variants, and vaccine-resistant variants could push the vaccinated part of the world back to square one.

Rich countries have already bought up far more than their fair share of vaccines, and ordering booster doses just exacerbates that problem.

"When we talk about boosting and revaccination, it's also important to bear in mind globally what is needed in terms of vaccination access where the progress has been much, much slower," says Tolullah Oni at the University of Cambridge's MRC Epidemiology Unit.

"If there's anything we can see from the tragedy that is playing out in India at the moment it is that, yes, we have to maximally suppress [the virus] locally but also do everything in our power to support vaccination access globally," she says. "That is a really critical point when we're talking about how to get out of this pandemic."

Immunosenescence

Covid-19 ages immune system

Long-term health problems may be down to prematurely aged immune cells

Graham Lawton

PEOPLE who survive severe covid-19 appear to end up with a prematurely-aged immune system and other persistent immunological problems, which may be the underlying cause of long covid.

The immune response to acute covid-19 is now well understood, but the longer-term effects are only just coming to light. The preliminary results from three studies looking into these long-term effects were reported last month at a virtual conference hosted by the UK Coronavirus Immunology Consortium and the British Society for Immunology. Together they suggest that the immune system gets a nasty hangover from the virus, but that it may be reversible.

In one study, Niharika Duggal at the University of Birmingham, UK, and her colleagues studied the immune systems of 46 people who had been hospitalised with severe covid-19. Three months after discharge, a significant number showed signs of premature immunosenescence: an age-related decline in the ability to mount an immune response. "We have seen a number of different features of accelerated immune ageing," says Duggal.

This included a loss of naive B- and T-cells, which are immature immune cells that have yet to be called into action against a pathogen. Duggal says they also saw another sign of immune ageing: accumulation of memory B- and T-cells, which remain in circulation after an infection, ready to respond to reinfection. Additionally, there was also an excess of senescent T-cells, which can secrete damaging chemicals, driving inflammation that may underlie many age-related diseases.

The subjects were aged between 30 and 68. Their immune systems were compared with a similar group who hadn't had covid-19. Immunosenescence usually starts around age 60, but the survivors under 60 showed signs of it, says Duggal.

Cause or effect?

This fits with what we already know about premature immune ageing. Earlier studies have shown that traumatic injuries and chronic diseases can age the immune system prematurely. This is the first study to suggest that a viral infection can do so too.

Given the design of the study, however, it isn't possible to rule out that the survivors became severely ill because they already had prematurely-aged immune systems. Immune age varies widely between individuals; somebody who is 40 years old can have an immune age of anything between 20 and 60.

"Is it cause or effect?" says team leader Janet Lord, also at the University of Birmingham. "Probably a bit of both, as an analysis of people in the UK Biobank who developed covid showed they were biologically 10 to 14 years older."

In a separate study, Verena Kaestele at the University of Manchester, UK, looked at neutrophils in about 50 people who experienced severe covid-19.

Neutrophils are general-purpose immune cells that patrol the body, destroying invading bacteria. They also promote inflammation, and are activated by viruses, including SARS-CoV-2.

Neutrophils usually constitute up to two-thirds of all white blood cells in the body. During an infection, their numbers increase rapidly and fall back to baseline after the infection has cleared. In some people with acute covid-19 neutrophil levels were elevated to 90 per cent of all white blood cells. "That cannot be healthy," says Tracy Hussell at the University of Manchester, who oversaw the study.

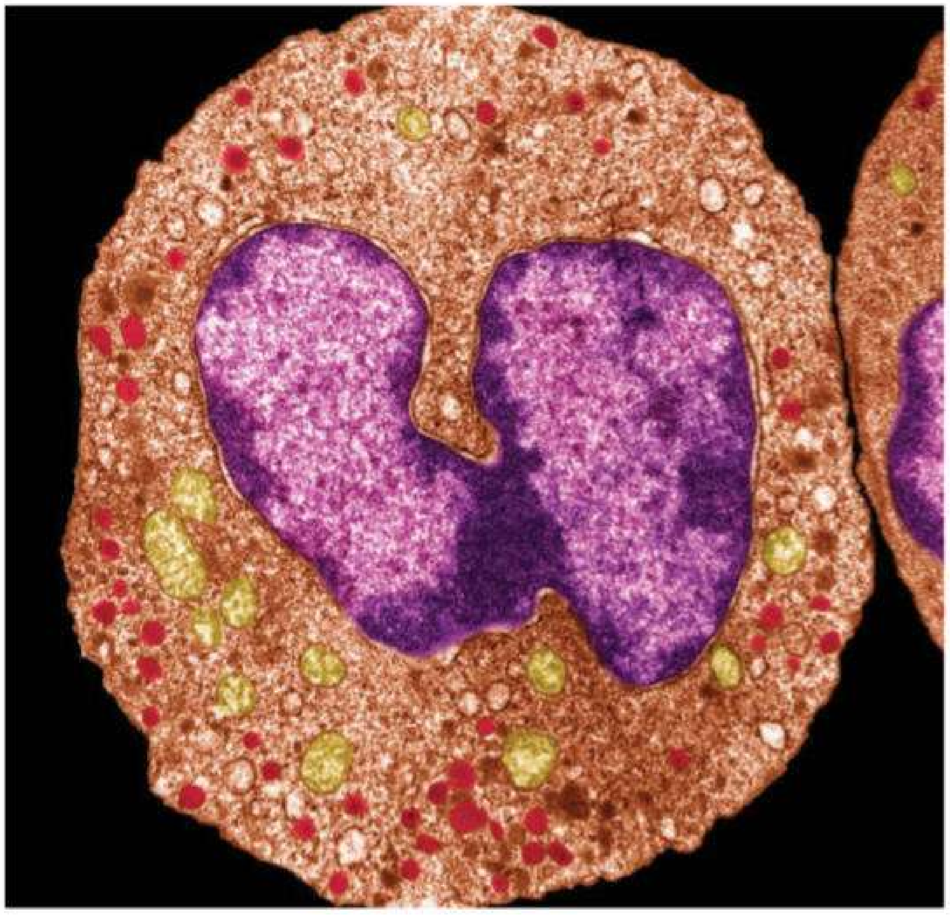
Demand for neutrophils is so high in these people that the bone marrow can't keep up and ends up cranking out immature neutrophils, which aren't fully functional and may contribute to the severity of disease, according to Kaestele.

> "We have seen a number of different features of accelerated immune ageing"

About half of the people in the study survived. Of these, Kaestele found that around a third had elevated and dysfunctional neutrophils up to 9 months after discharge from hospital. It is possible that this neutrophil imbalance contributes to long covid symptoms, says Kaestele. For example, there is some evidence that neutrophils promote excessive blood clotting, one symptom of long covid.

A third study found persistent changes in gene expression in the immune systems of some people with covid-19. The cause and effect of these changes isn't yet known, says Aimee Hanson at the University of Cambridge, who presented the research. But they may also be related to long covid.

All three studies are at an early stage and more data is needed to fully explain long covid. The good news is that interventions, such as exercise and diet, have been shown to reverse immunosenescence, so if severe covid-19 does cause premature ageing, the health consequences aren't necessarily irreversible. ▮



STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

A transmission electron micrograph of human neutrophil cells

New Scientist Discovery Tours

8 days | 30 October and 6 November 2021

Land of fire and ice: Iceland

Join an unforgettable tour of Iceland's majestic landscapes, scheduled to maximise days filled with volcanic and geological adventure, and evening opportunities to see the Aurora Borealis.

Spend time with leading geologist Oliver Shorttle, discovering the might of the planet as you marvel at the sights, sounds and smells of erupting geysers, hot springs, and bubbling mud. Plus, stunning glaciers, waterfalls and visible tectonic plates pulling apart. Staying at four different hotels to reduce travelling and see more of Iceland.

Highlights

- Join talks and walking seminars from Oliver Shorttle.
- Tour Þingvellir National Park, the site of Iceland's first parliament, founded in 930, and a geological wonder where the American and Eurasian tectonic plates are pulling apart.
- Visit Iceland's Geysir geothermal area, where you'll see the Strokkur geyser shoot water 30 metres into the air. Be spellbound by the immense beauty and sheer power of the Gullfoss Waterfall.
- Super jeep drivers will take you to the elegant Seljalandsfoss waterfall, which is unique in its kind, as you can walk behind the plummeting falling stream without getting (too) wet, for a unique viewing angle.
- Cross the deep and roaring rivers that guard the wooded surroundings of Thórsmörk, where you will have time to hike around the area and admire some of the many viewpoints it offers.
- A trip to the eerily beautiful Skógafoss waterfall, one of the biggest waterfalls in Iceland. 25 metres wide with a 60-metre drop. You will feel the immense power of the waterfall close-up, as you climb a long windy set of stairs to a truly stunning viewpoint.
- Visit the famous Jokulsarlon Glacier Lagoon, a stunning sea of floating icebergs. Weather permitting, there will be an opportunity to step outside and witness the natural wonders of the Northern Lights.
- Walk on Europe's biggest ice cap – Vatnajokull, which has around 30 glaciers flowing out from it.
- Enjoy lunch in the black sand seaside town of Vik. The sea on one side and high cliffs on the other, dramatically positions this quaint little village as Iceland's most southerly mainland settlement.
- Visit the Lava Centre, an interactive, high-tech educational exhibition depicting volcanic activity, earthquakes, and the creation of Iceland over millions of years.
- Relax in the warm thermal waters of natural hot springs in the village of Fludir.

Flexible deposits and covid-19 safety protocols including:

- Pre-departure screening of all guests and tour leaders.
- Increased sanitisation of all accommodation and transport.
- Mandatory use of PPE where appropriate.

In partnership with
Intrepid Travel

For more information visit newscientist.com/tours

Human evolution

Birth was difficult for ancient humans

New research suggests the dangers of childbirth date back further than we thought

Michael Marshall

IT ISN'T just modern humans that have found giving birth painful and dangerous. Growing evidence suggests birth was difficult for our hominin relatives millions of years ago. As a result, earlier hominins like *Australopithecus* may have needed help to deliver their babies.

Birth is strikingly dangerous for modern humans compared with other primates. Globally, for every 100,000 births in 2017, 211 mothers died.

The same isn't true for some other primates, including monkeys. "You're not seeing these types of complications that you see in humans," says Nicole Webb at the University of Zurich in Switzerland.

The long-standing explanation for the difficulty of human births is that it is caused by a combination of our large brains and the fact that we walk upright on two legs. According to anthropologist Sherwood Washburn, writing in 1960, upright walking meant evolution favoured a narrower pelvis, but also a wider pelvic canal to accommodate the baby's head – creating what he dubbed the obstetrical dilemma.

It was generally thought that the obstetrical dilemma was unique to humans, or at least to the *Homo* genus, but new evidence suggests birth difficulties go back much further.

Webb and her colleagues have examined the birth canals of chimpanzees, which were believed to be much more spacious than those of humans. In a talk at the annual meeting of the American Association of Physical Anthropologists, held online, she explained that this idea partly stems from a famous 1949 study by Adolph Schultz, which demonstrated that the entrance to the chimpanzee birth canal was almost twice as wide as the fetus's head.

However, Webb argued that Schultz measured the wrong parts of the pelvis: chimpanzee births work differently to human births, so the tightest fits are in different places. She then described how she made her own measurements of 29 chimpanzee pelvises and found that in the tightest spot, the fetus' head is 85 per cent of the size of the canal: still looser than what is found in humans, but not by much. "It's not like chimpanzees have all this space," says Webb.

She suggested there was a shift in the evolution of great apes, whose pelvises are different from those of monkeys. Many monkeys can stretch the cartilage that joins the left and right halves of the pelvis at the front, creating a wider opening, but chimpanzees and humans can't do that.

In another talk at the conference, Natalie Laudicina at Grand Valley State University in Allendale, Michigan, described how she had mapped the entire birth canals of five hominins: four *Australopithecus* specimens from three species, including the famous Lucy, and one Neanderthal.

With the exception of the 2 million-year-old *Australopithecus sediba*, all of the species she looked at faced a tight squeeze, and she says the babies would have had to rotate to get through the birth canal.

If *Australopithecus* had complicated births, mothers may have needed help during labour. "I think we've underestimated what *Australopithecus* [went] through," says Webb. Other adult females, perhaps those who had already given birth, may have acted as midwives. "I think it's something we need to entertain as a possibility," she says. ▮

Childbirth may have been difficult for ancient hominins

CHRISTIAN JEGOU PUBLIPHOTO DIFFUSION/SCIENCE PHOTO LIBRARY

Atomic physics

Neutron skin of an atom found to be very, very thin

THE "skin" of an atom has been measured for the first time.

Lead-208 is an isotope of lead that contains 82 protons and 126 neutrons, which are arranged neatly into shells inside the nucleus. As it has so many more neutrons than protons, the particles are only mixed together in the centre of the nucleus, with some neutrons forming a layer around the edge – the neutron skin.

The shells keep the atom relatively stable and make it simpler to experiment on, which is why the PREX collaboration at the Thomas Jefferson National Accelerator Facility in Virginia turned to lead-208 to measure neutron skin.

We already know the density of protons inside the lead-208 nucleus from previous experiments. As the neutron skin is created by the interior of the nucleus being so dense it squeezes some neutrons to the outside, measuring this neutron layer reveals the density of the nucleus as a whole.

"It tells us something fundamental about how nuclei are put together, and that piece of information really tells us how difficult it is to push neutrons into matter when there are already a lot of neutrons there, how hard it is to make matter more dense," says Kent Paschke at the University of Virginia, a spokesperson for the PREX group.

The researchers measured the thickness of the neutron skin by sandwiching a sample of lead-208 between two diamonds and bombarding it with a powerful beam of electrons. The way the electrons bounced off the lead revealed where in the nucleus the neutrons were located. The researchers found that the neutron skin is about 0.28 femtometres – 0.28 trillionths of a millimetre – across, very slightly thicker than physicists had predicted (*Physical Review Letters*, doi.org/gbwn).

Understanding this fundamental fact about nuclei could help us understand the pressure inside neutron stars, which are mostly made of neutrons. ▮

Leah Crane

"Measuring neutron skin tells us something fundamental about how nuclei are put together"

Space

Closest stars and exoplanets to the sun mapped in detail

Jonathan O'Callaghan

A COSMIC census of the currently known objects in the vicinity of our sun has revealed that there are 540 stars and planets in the immediate neighbourhood.

Using existing databases of objects alongside data from the European Space Agency's Gaia telescope, which is mapping billions of stars in our galaxy, Céline Reylé at the UTINAM Institute in France and her colleagues pooled all knowledge of objects within 10 parsecs, or 33 light years, of our sun.

While previous surveys have counted the stars in this region, no complete census has been made of the other known objects here too. These include planets and brown dwarfs, which are failed stars that never quite grew large enough to ignite nuclear fusion in their cores.

The total count reveals 540 known objects, not counting the sun and the eight planets of the solar system. That number is made up of 375 stars, 88 brown dwarfs and 77 exoplanets. "This list is as volume-complete as possible from current knowledge," says the team.

Of the stars in the census, 249 are small red dwarfs like Proxima Centauri, our closest neighbour at 4.2 light years away. The stellar count also includes 21 white dwarfs (dense remnants of dead stars), 18 G-type stars like our sun and two systems with five stars each (arxiv.org/abs/2104.14972).

While the number of stars is thought to be fairly accurate, there could be dozens more brown dwarfs that, so far, are too faint to spot. And the number of planets is very much a preliminary figure – most of the stars should have at least several worlds orbiting them.

Mapping objects out to a distance of 10 parsecs is useful, as it can give us a benchmark for the ratio of objects in the rest of the galaxy. "It's a golden sample for further observation," says Reylé. ▮

Cryptocurrencies

'Green' bitcoin alternative leads to hard disc shortages

Matthew Sparkes

NDREY RUDAKOV/BLOOMBERG VIA GETTY IMAGES

A cryptocurrency server farm in Nadvoitsy, Russia

CRYPTOCURRENCIES based on owning a large number of hard discs, rather than using computer processors, could offer a less energy-intensive alternative to bitcoin and might even make it cheaper to build data centres – although one is already causing soaring demand for hard discs that is disrupting supply chains.

Bitcoin and several other popular cryptocurrencies are created, or mined, using a concept called proof of work, which involves computations that use lots of electricity. The annual electricity consumption of bitcoin is estimated to be 148 terawatt-hours, or around the same amount as that of Poland. Now, rival currencies are emerging that instead make use of large numbers of empty hard discs, a concept called proof of space.

Because hard drives are less energy-intensive to run than processors, proof-of-space currencies are touted as being more environmentally friendly. However, demand for one such currency, Chia, has become so high that some Asian countries, such as Vietnam, are reporting shortages of hard discs. Currently, around 3 million terabytes of hard disc space are being devoted entirely to mining Chia, enough to store 3 billion movies.

Jason Feist at hard drive manufacturer Seagate says the company is experiencing strong orders and that staff are working to "adjust to market demand". He also suggested that these new cryptocurrencies could provide a way for firms building large data centres to offset the cost by turning spare capacity over to mining.

148

Estimated annual electricity use of bitcoin, in terawatt-hours

Michel Rauchs at the University of Cambridge says that although bitcoin's proof-of-work approach is well understood, proof-of-space alternatives are still only in their infancy.

"Other consensus algorithms that are less energy-intensive, but also introduce some level of centralisation and subjectivity, might be an acceptable trade-off. There are always trade-offs involved, most of which tend to only become known over time," he says.

Aron Peterson, who works in digital production for the film industry in the UK, says that people in his field started to notice the price of computing hardware creeping above manufacturer-listed prices around six years ago. He puts it down to the demand for graphics cards by people mining cryptocurrency, as these proved very efficient at the task.

"It was causing frustration among creatives and gamers who didn't want to purchase upgrades at inflated prices just because other people were wasting huge amounts of electricity to compete for digital tokens," he says.

After deciding to try mining himself, Peterson found that it was using significant energy. He also predicted that it would take five months for him to mine any coins. "Obviously, I wasn't going to run this experiment for five months, especially if the estimated time continued to climb as new miners appeared," he says.

Peterson isn't convinced by Chia's green credentials, saying that bitcoin miners are unlikely to switch because it would require them to buy new hardware. "Aside from the energy usage, this results in mountains of electronic waste as hard drives will fail faster and more often," says Peterson.

Chia Network, the firm behind the cryptocurrency, didn't respond to a request for comment. ▮

Archaeology

Cerne Abbas Giant may have been created over 1000 years ago

Michael Marshall

NATIONAL TRUST/BEN THOMAS

Archaeologists excavating at the site to look for quartz

A MYSTERIOUS chalk carving of a huge, naked man on an English hillside was made in the 10th century, according to the first attempt to archaeologically date the giant. The finding is unexpected because the earliest mentions of the Cerne Abbas Giant are from just over 300 years ago, suggesting it was forgotten for centuries.

Historians and archaeologists had many ideas about when the giant was constructed, says team member Mike Allen, an independent geoarchaeologist at Allen Environmental Archaeology in Codford, UK. "Everyone was wrong."

The giant is carved into a hillside overlooking the village of Cerne Abbas in southern England. It is a figure of a man with a large, erect penis, holding a club. It was made by digging trenches into the hillside, then filling them with white chalk.

The earliest known reference to the giant is from 1694, from the records of the church in Cerne Abbas. The giant is absent from earlier records, notably a 1617 survey of the area by John Norden, who was famously thorough.

Historians have argued for decades over when the giant was created and what it represents. Some believe it was made in the 1600s, in line with the historical records, while others think it dates to Roman times.

Allen is part of a team that carried out excavations on the giant in 2020, with the support of its owner, the National Trust. The researchers dug in the soles of both its feet and the crooks of its elbows.

The team looked for grains of quartz in the chalk and in the soil next to the trenches. A method called optically stimulated luminescence dating could then be used to determine when the quartz was last exposed to sunlight.

Using the technique, the researchers dated the oldest chalk to between AD 650 and 1310. The giant was probably created sometime between these dates, with the year AD 980 falling in the middle of that window. In theory, the giant might be older, because the chalking has been replaced several times. But the soil data suggests not. The oldest date for the soil is AD 700 to 1100. "[The giant] cannot be older than that," says Allen.

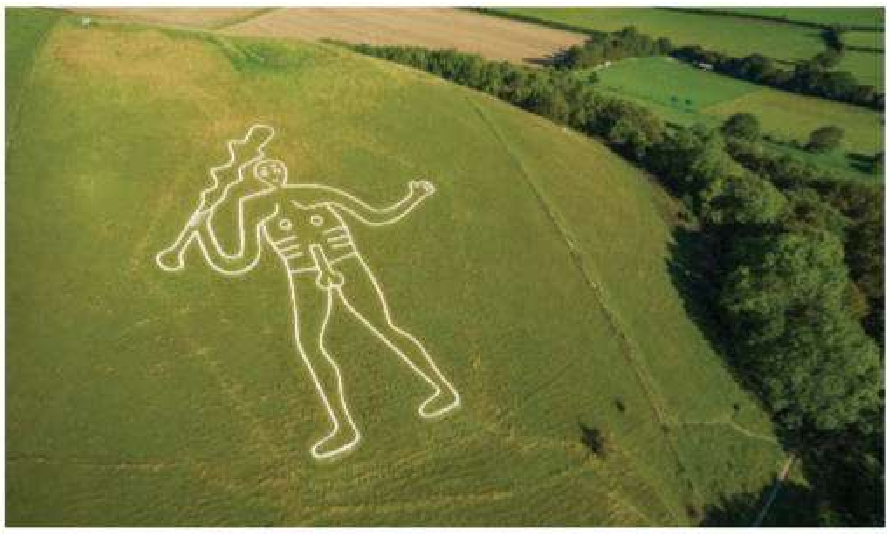
Intriguingly, a Benedictine monastery was founded in Cerne Abbas in the late 10th century. Allen speculates that the giant might represent a response to that.

"It would almost seem to be an act of resistance by local people to create this fantastically rude pagan image on the hillside," says Alison Sheridan, a freelance archaeological consultant based in Edinburgh, UK. "It's like a big two fingers to the abbey."

It isn't clear why there are no mentions of the giant for centuries. Allen says other findings from the excavation hint there was a time when the site was covered with long grass, suggesting the giant became overgrown and invisible.

However, Timothy Darvill at Bournemouth University, UK, says prehistoric monuments were often ignored. "Even sites like Stonehenge don't get that much mention," he says.

The giant is one of only three surviving "ancient" hill figures in England. The others are the Long Man at Wilmington and the Uffington White Horse. Only the horse can safely be said to be prehistoric, however. ▮


NATIONAL TRUST IMAGES/MIKE CALNAN/JAMES DOBSON

The Cerne Abbas Giant is older than many had thought

Ageing

Genes that stop DNA damage help people live past 105 years

Clare Wilson

PEOPLE who reach a very old age may have their genes to thank. Genetic variants that help prevent DNA mutations and repair any that do occur have been found in supercentenarians and semi-supercentenarians – who reach the ages of 110 and 105, respectively.

"DNA repair mechanisms are extremely efficient in these people," says Claudio Franceschi at the University of Bologna in Italy. "It is one of the most important basic mechanisms for extending lifespan."

Damage to DNA happens throughout our lives. It has many causes, including sunlight and natural radiation, as well as harmful compounds called free radicals generated by normal cell activity.

Centenarians' genes have long been studied by researchers of healthy ageing, but Franceschi's team is the first to sequence all the genes, or the whole genome, of a large group of people.

The researchers sequenced the DNA of five supercentenarians and 76 semi-supercentenarians from Italy, comparing them with 36 younger people from the same region, who had an average age of 68.

The team discovered five genetic variants were more common in the older age groups, which changed the expression of three genes (*eLife*, doi.org/gjvz7t). These variants were also more common in a group of 333 centenarians whose genes had been analysed in a previous study.

Earlier work suggests the variants should collectively reduce the number of mutations accumulating in cells by combating free radicals, coordinating each cell's response to DNA damage and encouraging damaged cells to die.

Franceschi's team discovered that the older individuals did indeed have fewer mutations in six out of seven key genes analysed. ▮

Thermodynamics

The cost of keeping time

As a clock is made more accurate, it produces more entropy, increasing disorder as it ticks

Leah Crane

KEEPING time accurately comes with a price. The maximum accuracy of a clock is directly related to how much disorder, or entropy, it creates every time it ticks.

Natalia Ares at the University of Oxford and her colleagues made this discovery using a tiny clock with an accuracy that can be controlled. The clock consists of a 50-nanometre-thick membrane of silicon nitride, vibrated by an electric current. Each time the membrane moved up and down once and then returned to its original position, the researchers counted a tick, and the regularity of the spacing between the ticks represented the accuracy of the clock.

The researchers found that as they increased the clock's accuracy, the heat produced in the system grew, increasing the entropy of its surroundings by jostling nearby particles (*Physical Review X*, doi.org/gjwmpb).

"If a clock is more accurate, you are paying for it somehow," says Ares. In this case, you pay for it by pouring more ordered energy into the clock, which is then converted into entropy. "By measuring time, we are increasing the entropy of the universe," says Ares.

The more entropy there is in the universe, the closer it may be to its eventual demise. "Maybe we should stop measuring time," says Ares. The scale of the additional entropy is so small, though, that there is no need to worry about its effects, she says.

By measuring time, we may be increasing the entropy of the universe

BRAIN LIGHT/ALAMY

The increase in entropy in timekeeping may be related to the "arrow of time", says Marcus Huber at the Austrian Academy of Sciences in Vienna, who was part of the research team.

It has been suggested that the reason that time only flows forward, not in reverse, is that the total amount of entropy in the universe is constantly increasing, creating disorder that cannot be put in order again.

The relationship that the researchers found is a limit on the accuracy of a clock, so it doesn't mean that a clock that creates the most possible entropy would be maximally accurate – hence a large, inefficient grandfather clock isn't more precise than an atomic clock. "It's a bit like fuel use in a car. Just because I'm using more fuel doesn't mean that I'm going faster or further," says Huber.

When the researchers compared their results with theoretical models developed for clocks that rely on quantum effects, they were surprised to find that the relationship between accuracy and entropy seemed to be the same for both.

"I think it's hinting at this universality of how the laws of thermodynamics apply to clocks," says Ares.

We can't be sure yet that these results are actually universal, though, because there are many types of clocks for which the relationship between accuracy and entropy haven't been tested. "It's still unclear how this principle plays out in real devices such as atomic clocks, which push the ultimate quantum limits of accuracy," says Mark Mitchison at Trinity College Dublin in Ireland.

Understanding this relationship could be helpful for designing clocks in the future, particularly those used in quantum computers and other devices where both accuracy and temperature are crucial, says Ares.

This finding could also help us understand more generally how the quantum world and the classical world are similar and different in terms of thermodynamics and the passage of time.

Technology

US Navy drone will exterminate birds' eggs near airfields

AN AUTONOMOUS drone being developed for the US Navy will seek out birds' nests near airfields, armed with a device to prevent their eggs from hatching.

Bird strikes are a serious risk to aircraft, and the US Pentagon spends around $50 million a year managing birds around airfields.

Oiling is a process that involves coating eggs with food-grade oil to block pores in the shells and deprive the embryos of oxygen. When carried out correctly, it is considered by the Humane Society of the United States to be a humane way to prevent embryos from developing, and it doesn't drive parent birds to start a new nest or lay more eggs. The method can selectively reduce populations of birds while protecting threatened and endangered species.

Drones have previously been used to locate birds' nests that could then be treated by human operators, but many of these nests are in inaccessible places including cliff faces, towers or other infrastructure.

Hitron Technologies in Lexington, Kentucky, is developing the Intelligent Remote Egg-Oiling System (IREOS) for the US Navy, in collaboration with the University of South Carolina. IREOS is a commercial quadcopter equipped with real-time nest detection based on deep learning, a form of machine learning inspired by the brain, and an egg-oiling device. Once a nest is identified, a human operator decides whether to go ahead with oiling.

"The drone can detect nests in real-time and coat eggs with food-grade oil to stop their development"

The IREOS prototype is currently carrying out flight tests in a controlled environment. Later field testing may require permits from the US Fish and Wildlife Service. The first version of the technology will be used by the US Navy, and a commercial version could follow for airport operators.

Graham White at the Royal Society for the Protection of Birds in the UK questions whether the drone could effectively oil an egg, including its underside. "Egg oiling can cause welfare issues for the adult birds," he says.

David Hambling

Sleep

Worrying you might get bad jet lag could actually make it worse

Jason Arunn Murugesu

JET lag may be partially in the mind. Eva Winnebeck at Ludwig Maximilian University of Munich, Germany, and her colleagues have looked at potential psychological causes of jet leg – the temporary impact of some long flights in which you feel out of sync with the time zone you have travelled to.

"In biology, when we think about a topic, we often think about what we can measure – like a molecule or something," says Winnebeck. "But a psychologist would think about the world very differently... what you think about a disease can have a huge impact on it."

The team asked 90 people to keep a sleep diary for a week before and after a long-haul flight in 2018. Before the flight, they were also asked whether they expected to get jet lag and how bad they thought it would be. After the flight, they were asked to detail what their jet lag was like every day for a week by quantifying symptoms on a 60-point scale.

The researchers also took into account whether the participants were travelling east or west and how many time zones they were due to cross – six, on average.

The team found that, on average, jet lag lasted for around four days, but that it was less common than people thought it would be. More than 75 per cent of the participants said they expected to get jet lag, but only 54 per cent did.

"This could be a form of the nocebo effect – when the expectation of harm leads to worse outcomes"

The direction of travel and the number of time zones crossed had no notable effect on the extent of jet lag. The researchers did find that people travelling from west to east took longer to go to sleep in the week post-flight, though this group didn't say that their jet lag felt worse compared with those who travelled the other way.

ROBERT ALEXANDER/GETTY IMAGES

A positive outlook might help you keep jet lag to a minimum

Previous research has shown that flying east has a bigger impact on sleep because it means having to try to nod off earlier than you are used to, which is harder than staying awake for longer.

Instead, the researchers found that a person's expectation of how bad their jet lag would be was the strongest predictor of how they said they felt. For every extra day someone expected their jet lag to last, the peak intensity of how bad they actually felt post-flight increased by a small amount. For example, someone who expected five days of jet lag reported a peak intensity nearly twice as high as someone expecting just one day (bioRxiv, doi.org/gbmd).

This could be a form of "nocebo" effect, a version of the placebo effect in which the expectation of harm can lead to a greater negative outcome, says Winnebeck.

"It could be a nocebo effect or it could be that the people who didn't worry about jet lag just went about their normal lives after their flight – which helped the body get in sync quickly," she says.

Environment

Many US cities will lose nearly all ash trees by 2060

AN INVASIVE beetle called the emerald ash borer will wipe out almost all ash trees on the streets of many US cities by 2060, modelling reveals.

Invasive pests and diseases, such as the fungus-caused Dutch elm disease, have had a devastating impact on certain types of tree in many places around the world.

Emma Hudgins at McGill University in Canada has previously found that despite the different nature of all these pests, it is relatively simple to model their spread because they are being transported by human actions, for instance, in firewood.

Hudgins and her colleagues have now applied this finding to model how the spread of insect pests that are already present in the US will affect trees in cities. The researchers discovered that the emerald ash borer (*Agrilus planipennis*) is set to have the biggest impact.

This Asian insect, first detected in the US in 2002, attacks all native species of ash tree. It is poised to wipe out most ash trees in forests and will hit cities hard too. Some, including New York, Chicago, Cleveland and Philadelphia, could lose 99 per cent of their ash trees by 2060, the model suggests. It predicts that the emerald ash borer will reach Seattle, but probably not the rest of the West Coast, as there are few ash trees in forests there (bioRxiv, doi.org/gbmb).

TOM UHLMAN/ALAMY

A tree killed by the emerald ash borer

The spread means cities will lose many of the benefits of urban trees until replacements grow. Greener cities are good for people's mental well-being, says Hudgins, and trees provide habitat for animals.

Clearing dead ash trees could cost each affected city up to $13 million, the team forecasts. "If they fall on someone, that's a huge liability," says Hudgins.

Cities replacing dead or diseased trees or planting new ones should choose a diverse mixture of pest-resistant species rather than having streets lined with genetically identical trees, she says.

Michael Le Page

Space exploration

Large kites flown by robots could help power Mars base

Leah Crane

A FUTURE long-term base camp on Mars could be powered by renewable energy generated by a giant kite flown by robots that harnesses high Martian wind speeds.

Producing and storing renewable energy on Mars is difficult. It is further from the sun than Earth, so it only gets 43 per cent of the sunlight Earth does, making solar power less effective. What's more, wind turbines are far too heavy to reasonably ship to Mars.

Roland Schmehl at the Delft University of Technology in the Netherlands and his colleagues have proposed a solution using a 50-square-metre kite. As it climbs higher through the sky, more of the cable with which it is tethered to the ground spools out from a large bobbin-like drum, and energy can be harnessed through the rotation of this drum.

Eventually the kite's height must be reduced and it is reeled in again. This uses power – but not as much as was generated while the kite climbed higher, say the researchers, so the end result is an energy-generating system.

The researchers say this system would be supplemented with 70 square metres of solar cells. The energy generated could be stored in the short term using batteries.

A longer-term storage system would be achieved by compressing carbon dioxide gas from Mars's atmosphere in underground caverns – this gas could later be decompressed to reclaim the stored energy. The whole system could provide about 127 megawatt-hours of energy per year (arxiv.org/abs/2104.09506).

"If we relate it to Earth, it would power about 20 households here in the Netherlands," says Schmehl. "[A Mars base camp] is basically one household, four to five astronauts with a small lab." ▮

Analysis **Social media**

The limits of Facebook's 'Supreme Court'

The social media giant has got itself in a muddle over whether to ban former US president Donald Trump, says **Matthew Sparkes**

THE Oversight Board, an independent body set up by Facebook to review difficult moderation decisions made by the social media giant, has said the firm was right to remove potentially incendiary posts by former US president Donald Trump.

The board also said that Facebook needs to follow its own rules and either ban Trump permanently from Facebook and Instagram or reopen his accounts, rather than leaving him with an indefinite suspension. Effectively, the board has passed a contentious, high-profile problem back to Facebook to decide on.

In January, as his supporters staged a violent protest at the US Capitol building, Trump posted messages on Facebook urging them to leave peacefully, but also alleging that the US election had been illegally tampered with to his detriment. Facebook swiftly removed the messages and eventually indefinitely banned him from the platform.

The Oversight Board has now said that Facebook wasn't following its own clear rules and that Trump's accounts should either be permanently deleted or that a time-bounded ban with a clear end point is needed. It has told Facebook that it has six months to reassess its actions and decide which route to take: reinstate the former president's accounts or delete them forever.

"In applying a vague, standardless penalty and then referring this case to the Board to resolve, Facebook seeks to avoid its responsibilities," the board said in a statement.

ASCANNIO/ALAMY

Donald Trump is currently suspended from Facebook

Here, the Oversight Board is echoing critics that say Facebook is using the board to protect itself from high-profile decisions, rather than the board serving as a real watchdog that holds the company to account. After one early decision about hate speech posts, Eric Naing from US civil rights group Muslim Advocates said that "instead of taking meaningful action to curb dangerous hate speech on the platform, Facebook punted responsibility".

In a 2018 interview, before the board was created, Facebook CEO Mark Zuckerberg suggested that a Supreme Court-like body could rule on Facebook's decisions. Much media coverage of the board refers to it as such, but it has no court-like powers.

10

The number of decisions sent to Facebook's Oversight Board

This is only the 10th decision the Oversight Board has been asked to make since the original members were announced in May 2020. So far, six of those have been made against Facebook's call and three – including the Trump decision, which is arguably the most sensitive of all – have backed the company. The final one was abandoned after the user in question deleted their post.

Matthias Kettemann at the Leibniz Institute for Media Research in Germany says the decision is "nuanced and kicks the ball back into Facebook's court". He says: "Trump can be punished, but not arbitrarily. And Facebook has to enter a reflection process on how its rules and procedures contributed to societal tensions."

Board member Nicolas Suzor, a law professor at Queensland University of Technology, Australia, says there are big challenges for Facebook to tackle, such as whether algorithms and human moderators are too strict on moderation and therefore impinge on free speech, or are too lax and allow hate speech to flourish. "These problems cannot be addressed until Facebook becomes more transparent about how the algorithms work," he says.

"The reason I joined the Oversight Board is that I've long been a critic of how Facebook wasn't, in my opinion, taking seriously enough the social problems it was contributing to," says Suzor. "I certainly wouldn't be here if I thought that we didn't have a shot at making Facebook better. I'm not so naive to think that's going to be easy."

In a blog post, Facebook's Nick Clegg said he believed the original decision was necessary and right. "We will now consider the board's decision and determine an action that is clear and proportionate. In the meantime, Mr. Trump's accounts remain suspended."

Regardless of the decision, Trump isn't waiting for his accounts to be reinstated. Last week, he launched a website on which he promises to issue updates from the desk of the former president.

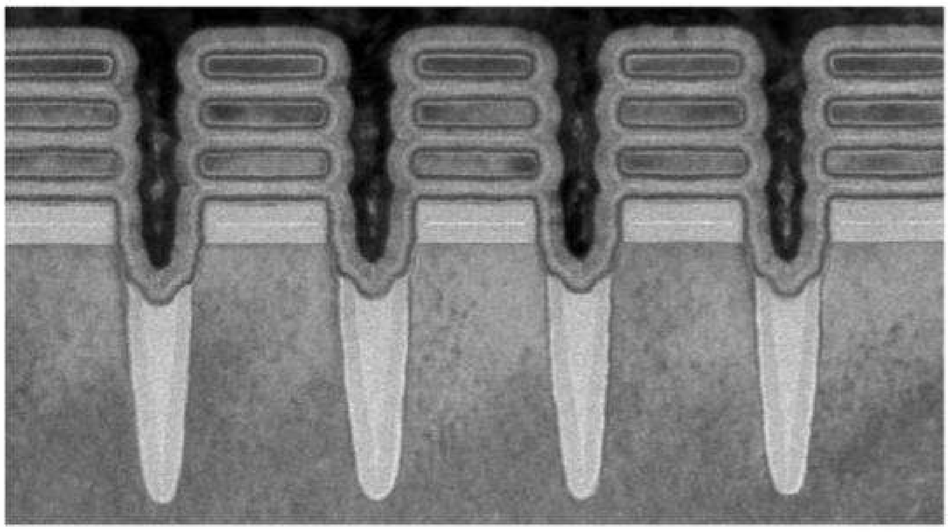
Facebook didn't respond to a request to comment. ▮

Computing

IBM's new climate-friendly chip

The world's first 2-nanometre chip could use 75 per cent less energy than those in use today

Matthew Sparkes


IBM

The new computer chip as viewed through an electron microscope

> **"Adoption of this technology could reduce the energy demands of data centres"**

IBM has built a working computer processor with 50 billion transistors in an area the size of a fingernail, making it the smallest and densest computer chip architecture yet produced. If it is adopted for use in data centres and consumer electronics, it could slash the vast amount of energy required for computing.

The computer chip manufacturing industry names generations of chip technology by size class, though these don't refer to the actual size of the chip. New commercial devices tend to use 7-nanometre or 5-nanometre chips. For instance, Apple's M1 chip in its current range of computers and the A14 chip that powers current iPhones both use 5-nanometre chips.

IBM claims that it has created the first working 2-nanometre chip. The transistors in this prototype are 12 nanometres wide, which is just 24 silicon atoms across. Decreasing the size of transistors can make chips smaller, faster and more efficient, reducing their power needs.

IBM says that 2-nanometre chips can be used in everything from phones and tablets to very high-performance server chips and supercomputers, and could achieve 45 per cent higher performance and 75 per cent lower energy use than the 7-nanometre chips in production today.

Steven Freear at the University of Leeds in the UK says that denser chips would bring a range of benefits beyond power efficiency, including greater reliability due to the ability to improve security and error checking.

Mukesh Khare at IBM says the prototype chip was made at the company's headquarters in Albany, New York, and that the process involves "hundreds and thousands of steps" in a 9300-square-metre clean room that runs 24 hours a day. IBM says that the chips will go into production in late 2024.

Chips as we know them today can be traced back to 1959 at Bell Laboratories in the US, where transistors were made by carefully oxidising a piece of silicon. The miniaturisation of chips is famously governed by Moore's Law, which states that the number of transistors on a processor will double every two years. This proved to be true for decades, but has slowed in recent years.

Kieran Brophy at Imperial College London says that improved chip design based on the transistor is rapidly approaching fundamental physical limits: "It's common knowledge that Moore's Law is breaking down. You fundamentally can't just keep going to smaller scales. You can't change physics."

Adoption of this technology could potentially help combat climate change by reducing the energy demands of the data centres that power email, social media and video streaming services. Data centres like this currently account for 1 per cent of the world's electricity use. ▮

Pregnancy

Blood test could predict when labour will begin

MANY pregnant women are eager to know exactly when they will give birth, and one day a blood test might be able to tell them.

At the moment, women are given a due date that is 40 weeks from the first day of their last period, but some give birth weeks before that, while others go beyond that date and may need to have labour induced.

Ina Stelzer at Stanford University, California, and her colleagues are investigating a new approach that involves tracking how the body responds to signals from the fetus and prepares for labour. "The blood shows that birth is approaching," she says.

Stelzer's team took between one and three blood samples from 53 pregnant women over their expected last 100 days of pregnancy and tested them in multiple ways. The researchers looked at nearly 5000 biochemicals and carried out more than 2000 tests on immune cells in their blood.

Two to four weeks before birth, the team found that there was a change in the women's hormone patterns and a fall in inflammatory immune cell activity, reflected by changes in the blood biomarkers.

The researchers built a prediction model using 45 of the biomarkers and tested this on a further 10 women. It predicted a probable delivery date that for each of them was within 17 days of their actual date, either before or after (*Science Translational Medicine*, doi.org/gbg3). Stelzer believes that as results from more women are added to the model, it will become more accurate. The researchers haven't yet tested if the model would work for multiple pregnancies or pregnant trans men.

45

Number of biomarkers used to predict when a woman would go into labour

If turned into a commercial test, it could be useful for knowing if pregnant women are likely to give birth prematurely, says Rachel Tribe at King's College London. At the moment this requires taking a swab of their vaginal fluid and doing a scan to measure the position of their cervix. ▮

Clare Wilson

WE'RE LOOKING FOR THE *best ideas in the world* ON BEHALF OF OLDER PEOPLE

The Ryman Prize is an international award aimed at encouraging the best and brightest thinkers in the world to focus on ways to improve the health of older people.

The world's ageing population means that in some parts of the globe – including much of the Western world – the population aged 75+ is set to almost triple in the next 30 years.

Older people face not only the acute threat of COVID-19, but also the burden of chronic diseases including Alzheimers and diabetes.

At the same time the health of older people is one of the most underfunded and poorly resourced areas of research.

So, to stimulate fresh efforts to tackle the problems of old age, we're offering a NZ$250,000 (£130,000) annual prize for the world's best discovery, development, advance or achievement that enhances quality of life for older people.

The Ryman Prize is awarded each year by the Prime Minister of New Zealand. It was first awarded in 2015 to Gabi Hollows, co-founder of the Hollows Foundation, for her tireless work to restore sight for millions of older people in the developing world.

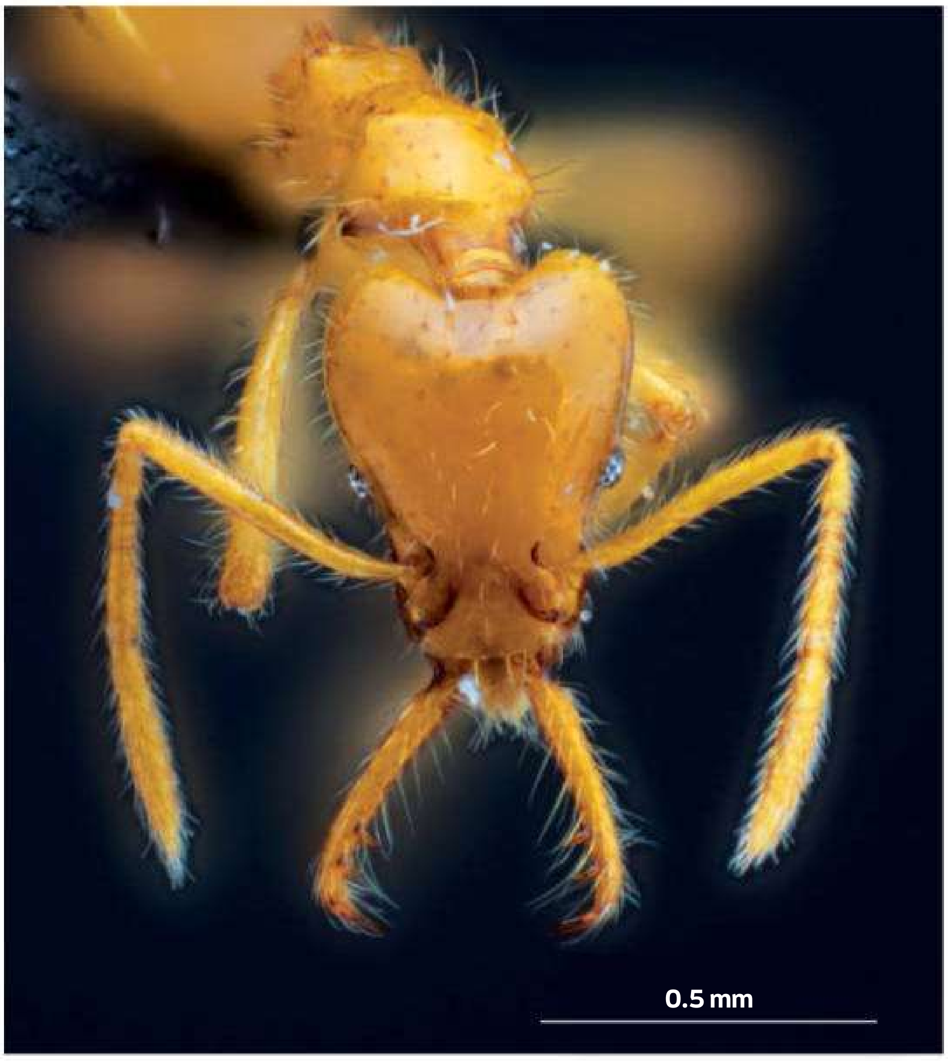
Since then world-leading researchers Professor Henry Brodaty, Professor Peter St George-Hyslop, Professor Takanori Shibata and Dr Michael Fehlings have all won the prize for their outstanding work.

In 2020 Professor Miia Kivipelto, a Finnish researcher whose research into the causes of Alzheimers and dementia has had a worldwide impact, was awarded the prize by the Right Honourable, Jacinda Ardern, Prime Minister of New Zealand.

If you have a great idea or have achieved something remarkable like Miia and our five other prize winners, we would love to hear from you.

Entries for the 2021 Ryman Prize close at 5pm on Friday, July 16, 2021 (New Zealand time).

Go to **rymanprize.com** for more information.



DOUGLAS B BOOHER, PHILIPP O HOENLE /ZOOKEYS.1036.62034

Animals

Ant gets non-binary species name to honour Warhol star

A NEWLY discovered species of ant from Ecuador has been named with the suffix "-they", rather than a traditional gendered Latin suffix, to celebrate gender diversity.

The ant was discovered in 2018 by Philipp Hoenle, who is at the Technical University of Darmstadt, Germany. He sent a photograph to taxonomic expert Douglas Booher at Yale University, who recognised it as a new species in the genus *Strumigenys*.

Traditionally, when naming a species after a person, one of two distinct genders are reflected by using the suffixes "-ae" for women and "-i" for men. Instead, Booher suggested using the gender non-binary identifier "they", naming the ant *Strumigenys ayersthey* after artist and human rights activist Jeremy Ayers.

Ayers was a protégé of Andy Warhol in the 1970s under the drag pseudonym of Silva Thinn. He died in 2016. "He identified as a gay man outside of his Warhol character, but I'm naming it after him with the suffix added to include all non-binary people for his activism," says Booher.

Booher also asked Michael Stipe, the lead singer of the band R.E.M. and a mutual friend with Ayers, to join him in writing the etymology section of the paper outlining the new species (*ZooKeys*, doi.org/gbk7).

Asked whether he will use the -they suffix to name future new species, Booher says he will use a female, male or non-binary suffix depending on the wishes of the person the species is named after.

Matthew Sparkes

Palaeontology

Prehistoric food chain frozen in time

IT'S a fish-eat-belemnite-eat-crustacean world. A pair of remarkable fossils appear to record the aftermath of a dramatic confrontation in the prehistoric ocean, when one predator was mid-meal only to be targeted by a bigger, hungry animal.

The state of preservation of the fossils is "amazing", says Christian Klug at the University of Zurich, Switzerland. The remains tell a story that sheds light on what was eating what millions of years ago.

Klug and his team studied the fossils of two marine organisms from the dinosaur era, which were about 174 to 183 million years old.

One of the animals is a belemnite (*Passaloteuthis laevigata*), a cephalopod related to modern squid and octopuses. Belemnites had a bony guard on their tail ends, which are the most commonly preserved bits.

This belemnite fossil had its bony guard, but also fragments of soft tissue and parts of the arms. Tangled up with the arms was a second fossil: a crustacean related to modern crayfish and shrimp from the genus *Proeryon*.

Crustaceans shed their skin when they grow, and modern cephalopods like to eat the skin. "They follow some crayfish so they can eat the moults," says Klug. He says the belemnite was probably doing the same thing. But the incompleteness of the belemnite suggests it didn't complete its meal. Klug says a larger predator seems to have targeted it and eaten most of its soft body parts, discarding the bony guard.

It isn't clear what ate the belemnite, but Klug suspects *Hybodus hauffianus*, a shark known to prey on belemnites and which probably learned not to swallow its bony guard, explaining why this body part was in the fossil (*Swiss Journal of Palaeontology*, doi.org/gbmm). **Michael Marshall**

Food science

Smart pasta takes shape when cooked

WE HAVE flat-pack furniture, now flat-pack pasta is in the offing.

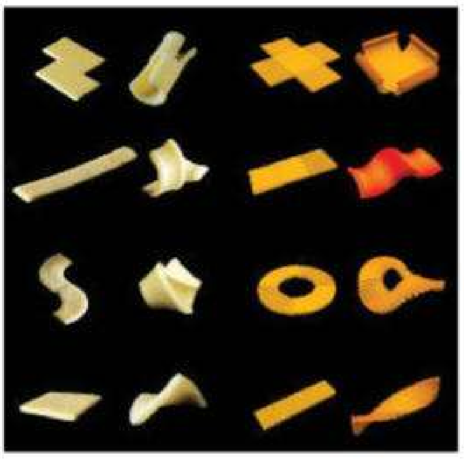
Wen Wang at Carnegie Mellon University in Pennsylvania and her colleagues have developed edible 2D pasta that swells into 3D shapes when cooked, such as long spirals resembling fusilli and saddle shapes.

The researchers believe that flat-pack dry pasta could drastically reduce the amount of packaging required for the foodstuff, as well as saving on storage and transportation space. For example, when macaroni is packaged, around 60 per cent of the space in the box or bag is air, estimates Wang.

The 2D pasta morphs into 3D shapes when boiled because each piece is lined with tiny grooves, less than 1 millimetre wide, in particular patterns. The grooves increase the surface area of some parts of a piece of pasta. Areas with a higher surface area absorb water and swell faster, which creates the shape, says Wang, who now works at food and drink company Nestlé.

The researchers made the product using an authentic Italian pasta dough recipe consisting of only semolina flour and water. Imprinting the grooves was the only additional step required.

Preliminary taste tests suggest that the pasta has the same taste and mouthfeel as the regular version (*Science Advances*, doi.org/gbmh). **Donna Lu**



MORPHING MATTER LAB. CARNEGIE MELLON UNIVERSITY

New Scientist Daily
Get the latest scientific discoveries in your inbox
newscientist.com/sign-up

Really brief

ROBERT ALEXANDER/GETTY IMAGES

Popular children in year group are older

Older school students are more popular than their younger peers in the same class, on average. That is the finding of a study of 14 and 15-year-olds in England, Sweden and the Netherlands (*PLoS One*, doi.org/gbmx). Older children also tend to do better academically, earlier studies suggest.

Benefits of limiting warming to 1.5°C

The amount of sea level rise as a result of ice melt could be halved if the world holds climate change to 1.5°C of warming. A review of computer models suggests there will be a 25 centimetre rise by 2100 with 3.4°C of warming, but just a 13 cm rise with 1.5°C of warming (*Nature*, doi.org/gbmw).

Owl-like dinosaur had night vision

A tiny, bird-like dinosaur, *Shuvuuia deserti*, had features that suggest its hearing and night vision were exceptionally good. The creature, which lived between 81 and 75 million years ago, may have been active at night like an owl, hinting that some non-bird dinosaurs were nocturnal (*Science*, doi.org/gbm2).

Evolution

Set of brain changes that made us human

THE key to human evolution may have been at the back of our minds all along. Some of the biggest biochemical differences between our brains and those of other primates are in the cerebellum, a region at the rear of the brain.

Scientists seeking to explain the evolution of our brains have often focused on the prefrontal cortex, which underpins our ability to consciously decide what to do.

In recent years, though, some have argued that the cerebellum has changed more than thought during our evolution.

To learn more, Elaine Guevara at Duke University in North Carolina and her colleagues studied the cerebellum and prefrontal cortex. They took samples from humans, chimpanzees and monkeys called rhesus macaques, and extracted DNA from both brain regions.

The team examined these to see which parts of the DNA had small molecules called methyl groups attached. This methylation is an example of a so-called epigenetic influence on our genes. Patterns of methylation reflect which genes have been active and inactive.

Guevara's team found that the pattern of methylation in human DNA was different to that in chimps and macaques. Crucially, the difference was greater in the cerebellum than the prefrontal cortex, suggesting more changes there during our evolution.

Some of the genes where the patterns were different are known to have a role in the strength of the connections between neurons, which is thought to be important for learning (*PLoS Genetics*, doi.org/gbmq). **MM**

Archaeology

HUTFON + CROW

Cosmopolitan crew went down with the Mary Rose

WHEN the Tudor warship the Mary Rose sank off England in 1545, it may have taken an international crew with it. An analysis of the remains of eight of its mariners suggests that some may have come from as far away as North Africa.

The Mary Rose served King Henry VIII for 34 years, before sinking during the Battle of the Solent against France. The ship was raised from the seabed in 1982.

Jessica Scorrer at Cardiff University, UK, and her colleagues have examined the ancestral origins and diets of eight of its crew. They took enamel from these people's teeth and analysed the chemical isotopes in it. The isotopes were influenced by their childhood food and drink and where they grew up.

Their analysis suggests that three of the crew may have originated from warmer, more southerly climates than those seen in Britain, perhaps on the southern European coast, Iberia or North Africa. The enamel of the remaining five crew members had isotope values consistent with a childhood most likely spent in western Britain.

However, one of those five had cranial characteristics typical of someone with African ancestry (*Royal Society Open Science*, doi.org/gbmg). **Karina Shah**

Conservation

Scarecrows at sea may save many birds

BUOYS with cartoon-like eyes act as scarecrows, keeping seabirds away from areas where they may get caught in fishing nets.

An estimated 400,000 diving birds drown each year when they become entangled in gill nets that hang in water between buoys.

A team of researchers led by Yann Rouxel at the BirdLife International Marine Programme in Glasgow, UK, has developed and tested a method of turning the buoys into marine scarecrows.

Based on previous studies of seabird vision and what changes their flight patterns, the team created its Looming-Eyes Buoy. It features a panel that rotates in the wind. On one side, it has a small pair of eyes; on the opposite side, is a larger pair of eyes. As it spins, it gives the impression of a creature that is appearing, or looming, in the field of vision.

This sort of looming has been shown to trigger "collision neurons" in the brains of birds to stop them hitting things.

In tests in Estonia's Küdema Bay, which sees many overwintering long-tailed ducks, their numbers dropped by up to a quarter within a 50-metre radius of each buoy (*Royal Society Open Science*, doi.org/gbmk). **Christa Lesté-Lasserre**

BACK IN STOCK

New Scientist Shop

NEW SCIENTIST JIGSAW PUZZLE

REACHING FOR THE MOON

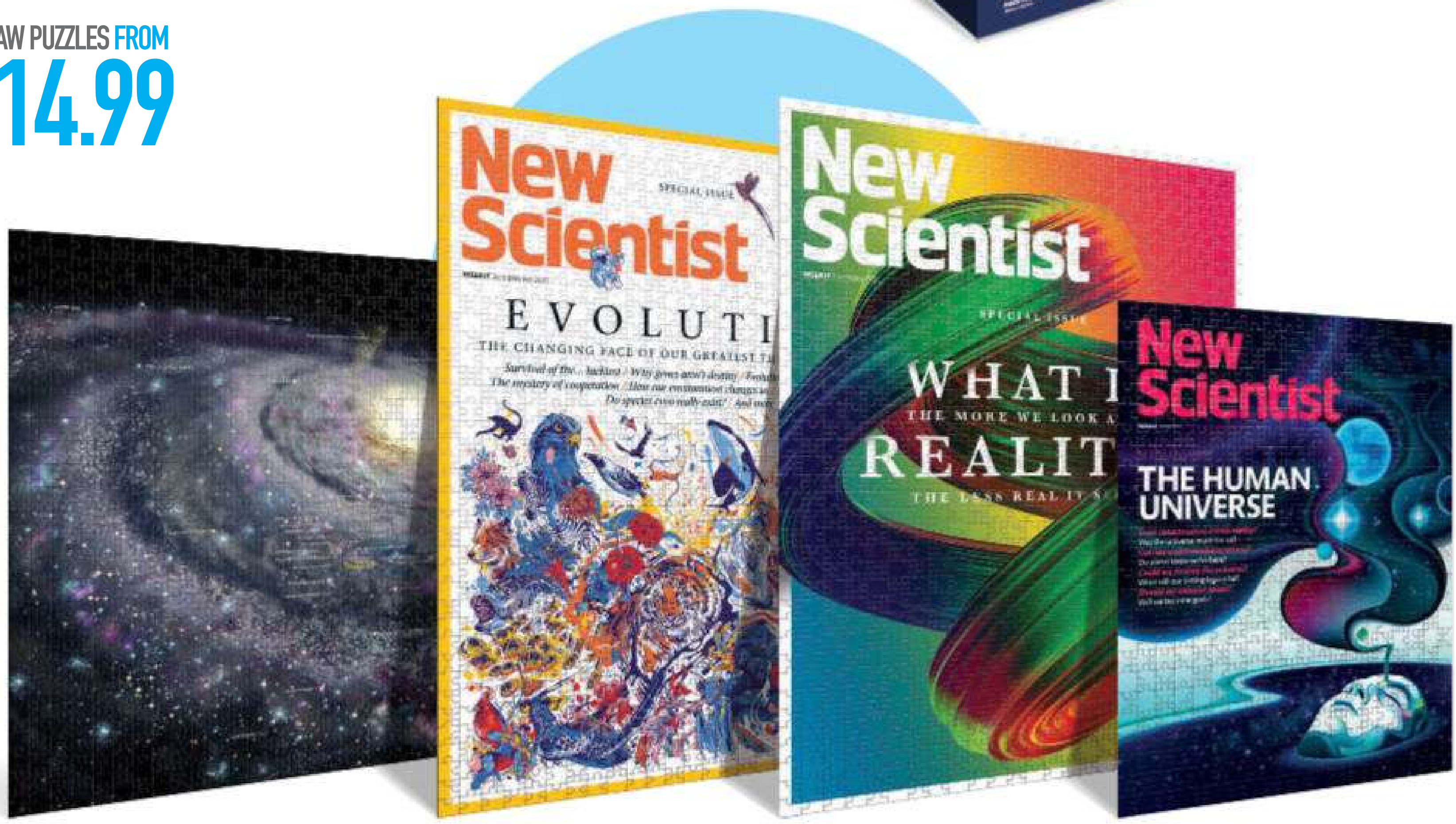
We are excited to announce our latest 1000-piece limited edition jigsaw puzzle is now **back in stock**. A beautiful detailed depiction of the near side of the moon, accompanied by details of all the missions to land there.

Our jigsaw puzzles are a delightful distraction from the stresses and strains of everyday life, plus they make perfect gifts. In a world where it's easy to get consumed by the sole pursuit of electronic gadgets, you'll find our unique jigsaw puzzle an entertaining and rewarding alternative.

Our bestselling Milky Way jigsaw puzzle is now back in stock, *so don't miss out!* All of our jigsaw puzzles include a special serial-numbered certificate and a sustainable cloth bag to hold the jigsaw pieces.

JIGSAW PUZZLES FROM

£14.99



shop.newscientist.com

worldwide shipping available

Views

The columnist
A new era of robots is coming, writes **Annalee Newitz** **p24**

Letters
Bend the ear of politicians to tackle the climate crisis **p26**

Aperture
Breathtaking photos of the Amazon and its people **p28**

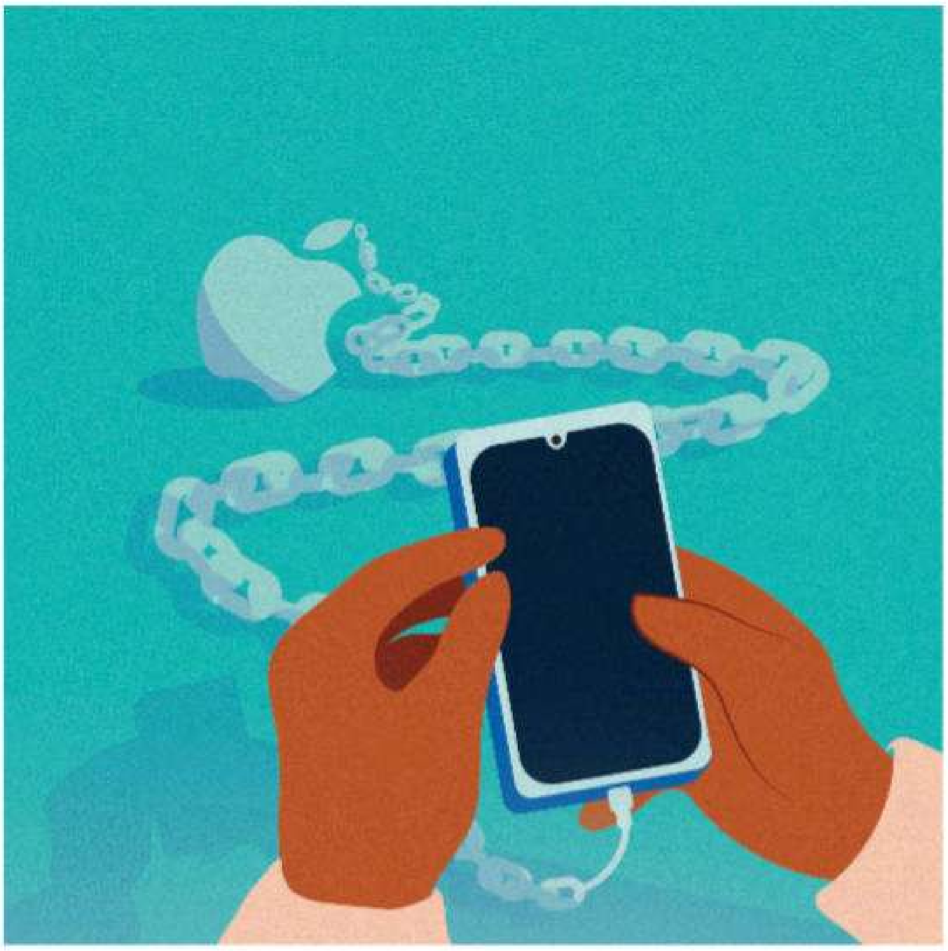
Culture
The case for ensuring life can survive on alien worlds **p32**

Culture columnist
Clare Wilson on a compelling new space opera **p34**

Comment

Goliath vs Goliath

A court case between Apple and Epic Games could decide the future of mobile apps and big tech companies, says **Frederike Kaltheuner**



MICHELLE D'URBANO

THE future of the rules used to regulate big tech companies hangs in the balance. Epic Games, the maker of online video game *Fortnite*, is currently taking on Apple in a US federal court in a trial that could not just decide how mobile apps operate, but also how technology firms can act in general.

It all began in 2020, when Epic Games launched an update of its iOS app that bypassed Apple's payment system, allowing it to take direct payment – a violation of Apple's terms of service. Apple typically takes a 30 per cent commission on every purchase made on the more than 1 billion iPhones around the world. The update meant it would miss out.

Apple promptly banned Epic Games from its App Store. Epic countered with a #FreeFortnite campaign that mocked an iconic Apple advert from the 1980s. The firm argues that Apple runs a monopoly with its App Store, which puts smaller app developers at a disadvantage, especially compared with Apple's own apps that can avoid the fee.

Although this may sound like a classic case of David versus Goliath – with the power of a dominant tech company being challenged – it is a lot more complicated than that.

Epic Games isn't a small developer, but a $29 billion company. And although Apple is a trillion-dollar tech firm, it also wants to be recognised as a champion of privacy and so fiercely opposes some of the most controversial practices of the tech industry.

The court will have to answer two key questions: is Apple running a monopoly with its App Store? And should it be allowed to take a 30 per cent revenue cut of every App Store purchase?

"These cases are difficult to win because it hinges on the court's definition of what a digital market is," says Anirudh Ekambaranathan at the University of Oxford. Epic Games argues that the App Store itself is a market in which Apple has a complete monopoly. Apple argues that games such as *Fortnite* can not only be played on all sorts of platforms, including Android as well as Apple phones, but also on devices like PlayStation.

Unlike Android, the iOS operating system only allows people to install apps directly from its App Store. This has advantages and disadvantages. One benefit of this centralised control is that Apple has a much tighter grip on privacy and security compared with Android. It also means that Apple can more easily impose its terms and conditions. This recently angered Facebook, when Apple introduced "app tracking transparency", a feature that makes it easy for users to opt out of detailed tracking on apps, an option that nearly all users are now choosing.

But Apple is also a powerful gatekeeper and has been accused of privacy hypocrisy. The company can decide what kinds of apps users are allowed to install on their phones, reducing choice for consumers. Apple also hasn't always enforced its own rules consistently. If Apple really objected to privacy-invading practices, which often violate its terms of service, it could take much more aggressive action during app reviews. Following a complaint by audio-streaming service Spotify, the European Commission recently published a preliminary view saying that Apple "distorted competition in the music streaming market" using its dominant market position.

No matter what the result of the US case, which will be decided by a judge, it is likely to have long-term implications for corporate power. If Epic Games wins, Apple will have to make major concessions in relation to how it runs its platforms. If Epic Games loses, this would give support to those who argue that current antitrust law isn't fit for purpose in reining in the dominance of the big tech firms and needs to be reformed. ▮

Frederike Kaltheuner is a tech policy analyst and the editor of *Fake AI*, which will be published this year

This changes everything

The uprising you never expected

Smart materials are helping redefine how we view robots. A new era of soft, shape-shifting and nanosized machines is coming, writes **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Future of Another Timeline* and they are the co-host of the Hugo-nominated podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

Annalee's week

What I'm reading

Andy Weir's novel Project Hail Mary, *which asks what would happen if our sun got a fungal infection.*

What I'm watching

The peregrine falcon nest cam at the University of California, Berkeley, where two wild falcons feed their adorable chicks chunks of flesh every day.

What I'm working on

The final bit of my almost-finished novel, featuring a sentient flying train who loves strategy games.

This column appears monthly. Up next week: James Wong

BACK in the early 2000s, an awesome thing happened in the *New X-Men* comics. Our mutant heroes had been battling giant robots called Sentinels for years, but suddenly these mechanical overlords spawned a new threat: Nano-Sentinels! Not content to rule Earth with their metal fists, these tiny robots invaded our bodies at the microscopic level. Infected humans were slowly converted into machines, cell by cell.

Now, a new wave of extremely odd robots is making at least part of the Nano-Sentinels story come true. Using exotic fabrication materials like squishy hydrogels and elastic polymers, researchers are making autonomous devices that are often tiny and that could turn out to be more powerful than an army of Terminators.

Some are 1-centimetre blobs that can skate over water. Others are flat sheets that can roll themselves into tubes, or matchstick-sized plastic coils that act as powerful muscles. No, they won't be invading our bodies and turning us into Sentinels – which I personally find a little disappointing – but some of them could one day swim through our bloodstream to heal us. They could also clean up pollutants in water or fold themselves into different kinds of vehicles for us to drive.

These creations are expanding the definition of what counts as a robot. Their special powers come from what they're made of, not from on-board software or bulletproof carapaces. And they are becoming so common that the journal *Science Robotics* recently devoted an entire issue to "smart" materials for making robots.

The issue's co-editors, biororoboticist Cecilia Laschi at the National University of Singapore and engineer Robert Wood at Harvard University, wrote that "as materials become smarter and more advanced, the boundaries between robots and materials will become less apparent".

Unlike a traditional robot, which is made of mechanical parts, these new kinds of robots are made from molecular parts. The principle is the same: both are devices that can move around and do things independently. But a robot made from smart materials might be nothing more than a pink drop of hydrogel. Instead of gears and wires, it's assembled from two kinds of molecules – some that love water and some that avoid it – which interact to allow the bot to skate on top of a pond.

> **"Robots that are wholly or partly made of gloop aren't the future I was promised in science fiction"**

Sometimes these materials are used to enhance more conventional robots. One team of researchers, for example, has developed a different kind of hydrogel that becomes sticky when exposed to a low-voltage zap of electricity and then stops being sticky when the electricity is switched off. This putty-like gel can be pasted right onto the feet or wheels of a robot.

When the robot wants to climb a sheer wall or scoot across the ceiling, it can activate its sticky feet with a few volts. Once it is back on a flat surface again, the robot turns off the adhesive like a light switch. Robots that are wholly or partly made of gloop aren't the future that I was promised in science fiction.

But it's definitely the future I want. I'm especially keen on the nanometre-scale "soft robots" that could one day swim through our bodies. Metin Sitti, a director at the Max Planck Institute for Intelligent Systems in Germany, worked with colleagues to prototype these tiny, synthetic beasts using various stretchy materials, such as simple rubber, and seeding them with magnetic microparticles. They are assembled into a finished shape by applying magnetic fields. The results look like flowers or geometric shapes made from Tinkertoy ball and stick modelling kits. They're guided through tubes of fluid using magnets, and can even stop and cling to the sides of a tube.

One day, soft robots like these could float through blood vessels to repair tissues or clear blockages. They won't have to be confined to our circulatory system, either.

Sometimes, doctors want to deliver medicines to parts of the body that aren't easily reached by blood vessels, such as the places between our organs, where infections and unwanted tissue growths can take root. Soft robots will travel to those places too. Perhaps, in a century, kids will get a dose of soft robots instead of childhood booster vaccines. They'll float harmlessly through our bodies, ready to be activated when needed.

Imagine buying robot goo in a can and smearing it on your shoes to go rock climbing. Or pouring it out on your decking to clean up some nasty mould. What about a building made of robots that can fix cracks before they become a problem?

Maybe, in 200 years, it will be hard to tell the difference between which parts of us are smart materials and which parts are old-fashioned biology. ▮

YEMEN EMERGENCY APPEAL

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

MSF anaesthetist Lenka Červeňová and her team care for a four-year-old boy after surgery in Dhi As-Sufal hospital in Yemen's Ibb province. Photograph © Majd Aljunaid/MSF

ALISON CRIADO-PEREZ IS AN MSF NURSE WHO WORKED IN MARIB

The conflict in Yemen is now in its sixth year. In Marib in central Yemen, nearly three million people have been displaced from their homes and are living in makeshift camps close to the frontline. Pregnant women and children are in desperate need of medical care.

"When we arrived in Marib, we found the local hospitals overwhelmed by the sheer number of people and by an influx of war-wounded. Around 2.7 million people are in the province now, many of them displaced from their homes elsewhere and looking for a safe haven.

People were living in makeshift shelters made of plastic and metal sheets. There were no latrines, just pits dug in the ground outside the tents. People were very worried about their health, about the risk of disease, about not having enough food. We were very concerned about the health of mothers and children, and pregnant women were a major worry too.

Over the next month, our small team worked around the clock to set up clinics providing basic healthcare and to supply hospitals that were struggling. Getting medicines to this part of Yemen wasn't easy. Supplies often had to cross frontlines. One of our trucks carrying antibiotics, medicines and other supplies was hijacked. It was an incredibly difficult environment to work in.

Along with general healthcare, we provided routine vaccinations for children and offered antenatal and postnatal care. We saw a lot of pregnant women and children and were able to refer pregnant women with complications to larger hospitals for emergency caesareans. It made a real difference.

A DESPERATE SITUATION

The day we started working in a rural hospital near the frontline, a woman came in with a breech delivery who was having real difficulty. Our midwife assisted and everything went well. But who knows what would have happened to that woman if the hospital wasn't there.

Since I left, many more people have come to the area. But Marib is no longer a safe place to be. In recent weeks, the frontlines have moved into the province, causing large numbers of injuries and forcing thousands more people to flee their homes. As the frontline approaches Marib city, we are concerned that people sheltering in the area may find themselves with no place else to go.

After six years of conflict, the situation is desperate. These people need our help now more than ever."

WHAT IS HAPPENING IN YEMEN?

Yemen is in the midst of civil war. After six years of conflict, the medical and humanitarian situation in Yemen continues to deteriorate. Poverty is widespread, malnutrition is on the rise and people are confronted by the daily threat of violence.

Pregnant women struggle to access medical care.

Infant and maternal mortality are on the rise as mothers and children bear the brunt of an increasingly brutal conflict.

MSF teams are providing urgent medical care to people caught up in this crisis. We work in 12 hospitals and health centres and support more than 20 hospitals and health facilities across the country.

We provide medical support in emergency rooms, maternity wards and outpatient departments, conduct surgeries, and run mobile clinics in rural towns and villages. The situation remains desperate. **We need your help now more than ever.**

THANK YOU

£44	could pay for three safe delivery kits to assist women giving birth.
£130	could provide an oxygen kit to help care for premature babies with underdeveloped lungs.
£228	could cover the cost of a midwife working in a field hospital for three days.
£866	could pay for a portable ultrasound device to monitor the health of pregnant women and their foetuses.

DONATE NOW

CALL 0800 055 79 84

Or search 'MSF NURSE' to make an online donation

YES, I would like to support MSF's medical teams in Yemen

I WOULD LIKE TO MAKE A DONATION OF £

Please make your cheque/charity voucher payable to Médecins Sans Frontières UK

OR ☐ Please charge my VISA/Mastercard/Amex/CAF card:

Cardholder name

Card number

Expiry date ☐☐/☐☐

Signature

Today's date ☐☐/☐☐/☐☐

Title

Forename(s)

Surname

Address

Postcode

Telephone

Email

HEAR FROM MSF BY EMAIL. Sign up to our monthly email, Frontline, which provides first-hand accounts of our work. You will receive Frontline, occasional emergency appeals, requests for donations and event invitations.

☐ Opt me in to email

Charity Registration Number 1026588

ARE YOU A UK TAXPAYER?

giftaid it

If so, you can make your gift worth 25% more at no extra cost. Please tick the box below.

☐ I wish Médecins Sans Frontières (MSF) to treat all gifts in the last 4 years, this gift and all future gifts as Gift Aid donations. I am a UK taxpayer and understand that if I pay less Income Tax and/or Capital Gains Tax than the amount of Gift Aid claimed on all my donations in that tax year it is my responsibility to pay any difference.

Date ☐☐/☐☐/☐☐

NB: Please let us know if your name, address or tax status changes, or if you would like to cancel this declaration, so that we can update our records.

RESPECTING YOU AND YOUR PERSONAL DATA

Your support is vital to our work and we would like to keep you informed with first-hand accounts from our staff and patients about the lifesaving impact your support is having, from combatting epidemics to providing emergency surgery.

We won't allow other organisations to have access to your personal data for marketing purposes and we won't bombard you with appeals.

By supporting MSF, you will receive our quarterly magazine Dispatches, event invitations,and occasional emergency appeals with requests for donations by post. You can change how you hear from MSF UK by emailing **uk.fundraising@london.msf.org** or calling **020 7404 6600.**

Visit our privacy notice for more: **msf.org.uk/privacy.**

Please fill in this form, place in an envelope and return postage free to: FREEPOST RUBA-GYZY-YXST, Médecins Sans Frontières, Bumpers Way, Bumpers Farm, Chippenham SN14 6NG. Alternatively you can phone 0800 055 79 84.

100538

MSFR0048

Editor's pick

Bend the ear of politicians to tackle the climate crisis

24 April, p 34

From Gareth Ackland, London, UK

Your excellent feature on the climate emergency was helpful in including a "What can I do?" section. While the effect of a person's lifestyle changes is dwarfed by the impacts that governments can make, if enough of us commit to reducing our carbon footprint, it can still accomplish a lot.

However, the best option for an individual is surely to collapse that power gap. Organisations such as Hope for the Future and Citizens' Climate Lobby insist that the most significant action a person can take is to engage their elected representatives in the problems we face and their possible solutions.

Those of us who live in democracies often forget that the wheels of power are intended to be subject to our views and interventions. If you aren't bending your government's ear, then who is?

From Susan Payne, Cape Elizabeth, Maine, US

I urge readers who are concerned about climate change to take action with others and join some of the environmental, advocacy, political or faith-based organisations that are working on this critical problem. This has many benefits, including developing a sense of community and solidarity that can counteract the growing issue of climate anxiety.

Half doses could help make vaccines go further

1 May, p 7

From Andrew Hicks, Sydney, Australia

With the Oxford/AstraZeneca vaccine, some evidence suggests that half the current standard dose would be at least as effective. In view of the desperate shortage of vaccines in India at the moment, perhaps we could save lives by stretching supplies of that vaccine, if it were established that a lower dose was safe and worked well.

Sentient trees? Best respect your elders

1 May, p 39

From Steve Tunnicliff, Long Clawson, Leicestershire, UK

So trees may have a form of sentience. Now I know that if I have to cut any elder, I must apologise and explain to the plant or face the consequences. Elder may or may not be sentient, but folklore says it is witchy and potentially vengeful. Best not take the chance.

Black hole disaster in our backyard is very unlikely

Letters, 24 April

From Eric Kvaalen, Les Essarts-le-Roi, France

Martin Watson and Tim Johnson worry about a possible black hole orbiting the sun colliding with it or another, similar black hole. In order for it to hit the sun, the very large angular momentum that the black hole would have as it orbits would need to be brought close to zero. The chance of that is very small.

Similarly, the likelihood of two planetary mass black holes colliding in our neighbourhood is very low. If a black hole has the mass of Earth, say, then its diameter is about 9 millimetres.

Cooling paint may help ease water shortages

24 April, p 19

From Jim McHardy, Clydebank, Strathclyde, UK

An ultra white paint has been invented and suggested as a means of cooling houses as potently as air conditioning.

However, perhaps it could also be used to provide a supply of fresh water. A horizontal, slightly conical metal sheet that was painted white on top would cool and condense water vapour beneath it. With the point of the cone facing downwards, the condensate would run down and be available for collection.

From Pamela Manfield, The North, Monmouthshire, UK

Is there a flaw in the idea of using super white, cooling paint on buildings in some places? Yes, sunlight will be deflected in summer so less air conditioning will be needed, but what about in winter? Presumably, its effect may mean more heating is needed then.

Algae can make biofuel without trashing Earth

10 April, p 41

From Guy Cox, St Albans, New South Wales, Australia

In your look at the links between biodiversity and climate change, you state that "measures to limit warming often don't take biodiversity into account. Some, such as the push for biofuels, directly harm it." However, microalgal systems offer significant opportunities to produce renewable biofuels without affecting farming or biodiversity.

From Lucy Roberts, Wantage, Oxfordshire, UK

Of all the arguments for GM crops, the idea that growing them intensively will release farmland for wildlife is the one I find least persuasive. It seems to be based on the idea that once we grow a certain quantity of food, we will say "that's enough".

The evidence suggests otherwise: modern farming already produces "enough" food. Michael Le Page points out that if we all ate a plant-based diet, we could allow three-quarters of farmland to return to a more natural state. Instead, we choose to produce less efficient, more luxurious food. I see no indication that we have reached the limit of our ability to consume more.

Nuclear plants can now deal with coastal breaches

Letters, 10 April

From Philip Belben, Nettlebridge, Somerset, UK

Steven King worries about possible tsunamis affecting nuclear power plants in the UK.

However, much of the nature of the Fukushima disaster in Japan resulted from a design that took no account of the possibility that sea defences might be breached. Emergency power supplies were vulnerable to inundation and were rendered inoperable just when they were most needed.

This mistake isn't being made again, with all nuclear power stations planned in the UK (and all of the ones I am aware of in other coastal locations) having to show that they can remain safe when sea defences are breached.

Aliens, if they visit us, really will be green

10 April, p 12

From David Brock, St Arnaud, Victoria, Australia

Your story on the high likelihood of alien civilisations experiencing a climate crisis akin to ours seems to presume that all intelligent life will be destructive. This is only true if life tends to follow the religious notion that a planet is a gift from god to use as it wishes. The view of many Aboriginal Australians, that we are responsible for the land, is better. This bestows nature with a god-like status.

I suspect an advanced alien civilisation could only exist long enough to conquer deep space by adopting that view. If aliens did visit us, I expect they would not be destructive invaders, but wise and respectful scientists. ▮

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, 25 Bedford Street, London WC2E 9ES will be delayed

LAST CHANCE TO REGISTER

New Scientist Events

BIG THINKERS SERIES

SUSAN SCHNEIDER

ARTIFICIAL INTELLIGENCE

Thursday 20 May 2021 6-7pm BST, 1-2pm EDT and on-demand

Given the rapid pace of progress in AI, many predict that machine minds could advance to human-level intelligence within the next few decades – and from there quickly outpace us.

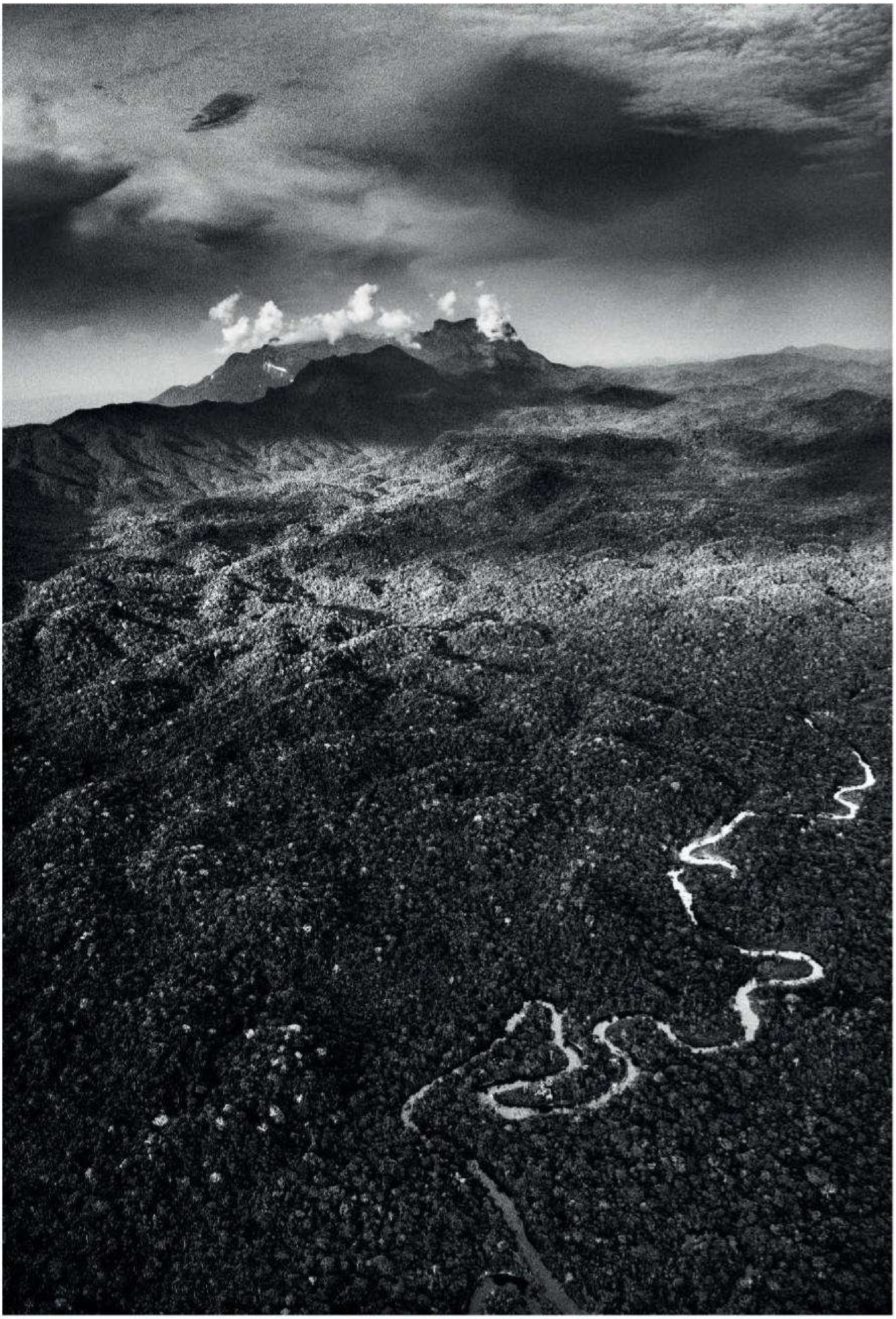
In this talk, philosopher and AI specialist Susan Schneider looks both outwards and inwards to ask what that means for the future of the mind, arguing it is inevitable that AI will take intelligence in new directions.

But will AI minds necessarily be conscious – and how will we find out? And in playing with tools such as mind, consciousness and the self that we don't yet fully understand, what dangers are we creating for ourselves?

For more information and to book your place visit:

newscientist.com/ai-event

BIG THINKERS SERIES
SUSAN SCHNEIDER



Amazonian awe

Photographer Sebastião Salgado

THESE stark black and white images of the Amazon and its culture capture nature's power and hint at the area's precarious future. The shots are by documentary photographer Sebastião Salgado and come from his latest collection, *Amazônia*, which highlights the lush Amazon rainforest and the complex worlds of its Indigenous communities.

Over six years, Salgado visited a dozen different groups scattered throughout the Amazon, documenting their daily lives, ceremonies and culture.

The largest image (far left) shows the Maiá river in Pico da Neblina National Park in north-western Brazil. The park overlaps with the territory of the Yanomami, whose population of some 38,000 across an area twice the size of Switzerland makes them one of the largest groups of Indigenous people in the Amazon. Next is the mountain range near the Marauiá river (near left, top), another landmark in the Yanomami Indigenous Territory.

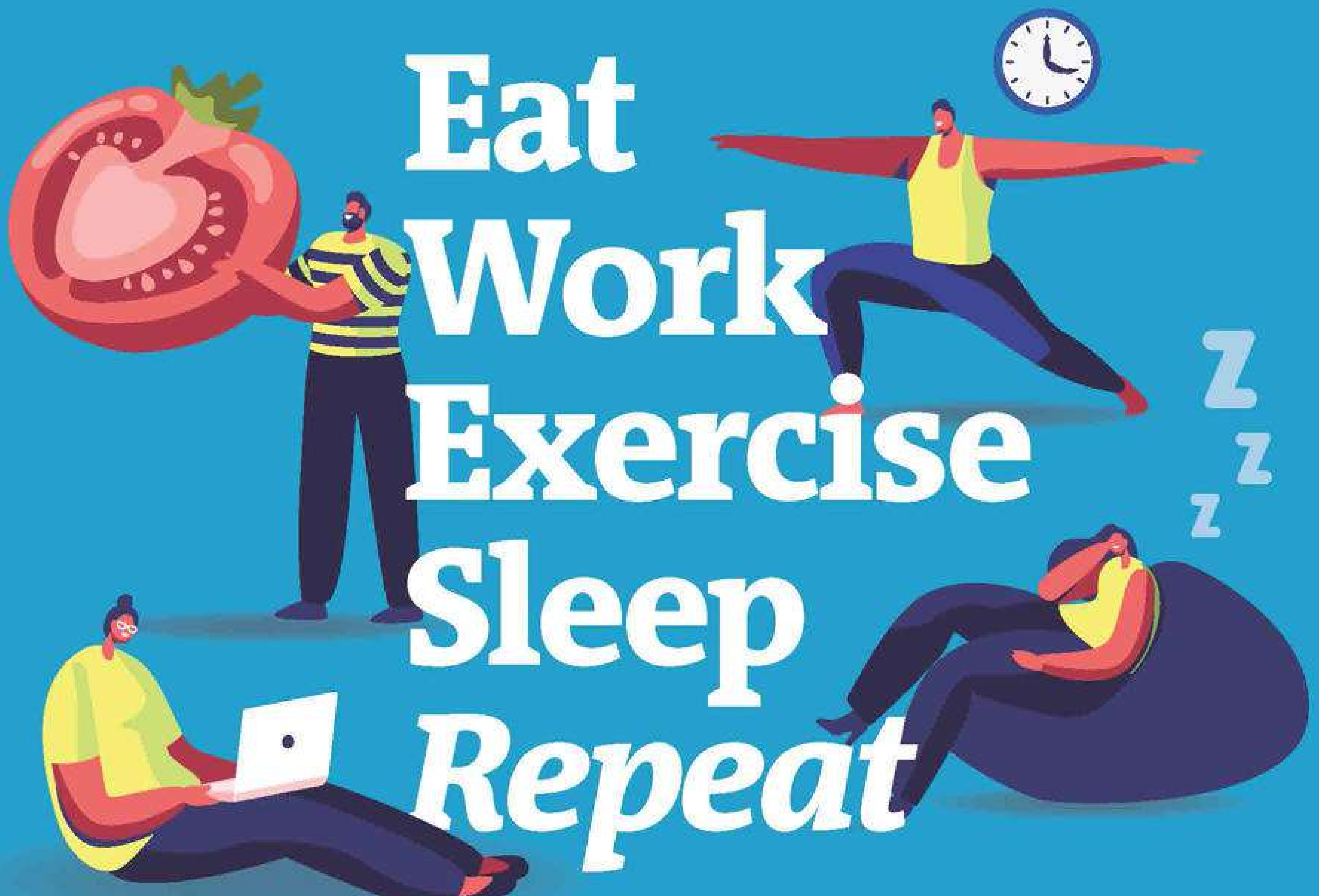
The image below it shows Miró, who is a member of another Indigenous Amazonian community called the Yawanawá. He is shown making feather adornments, an art that is a quintessential part of Yawanawán culture, as well as that of some other Indigenous communities.

Salgado dedicates *Amazônia* to the Indigenous peoples he met and photographed in the hope that deforestation and other destructive projects in the region won't make the book "a record of a lost world".

Amazônia is published by Taschen on 20 May. ▮

Gege Li

New Scientist
Subscriptions



For many of us, life during covid lockdowns was life stripped down to the basics – and it made us all the more aware how important it is to get those basics right.

From the latest insights on physical and mental health to evidence-based advice on diet and exercise, *New Scientist* has it covered. As life starts to blossom again in 2021, let science help your well-being blossom too.

Subscribe today and pay just £2.71 an issue*

Get so more than just the print edition:

51
print editions through your letter box

365
days of unlimited access to newscientist.com

400+
issues in the *New Scientist* app (including the current issue)

200+
video science talks to immerse yourself in

200+
interactive puzzles and crosswords (added weekly)

4
exclusive subscriber-only online events

Visit newscientist.com/12weeks

Call: +44 (0) 330 333 9470, quoting 16484

INTRODUCTORY OFFER
HALF PRICE
FOR 12 WEEKS

New Scientist.
The world, better understood

Offer closes 3 June 2021. *Weekly price of £2.71 based on print + app + web subscription package charged on the 12-week introductory offer. You can cancel anytime. Cancellations take effect at the end of your current billing period. Offer not open to current subscribers. Subscriber benefits based on an annual subscription.

How to engineer a future

A timely book argues that our duty to all life on Earth is to ensure its future by bioengineering it to survive on other worlds, finds **Simon Ings**

Book

The Next 500 Years: Engineering life to reach new worlds

Chris Mason

MIT Press

GIROSCIENCE/SCIENCE PHOTO LIBRARY

Genetic-engineering tools like CRISPR may help us live on harsh alien worlds

HUMANITY's long-term prospects are weak, at best. If we don't all kill each other with nuclear weapons, a planet-killing asteroid can't be too far off. And anyway, the sun itself will (eventually) expand, obliterating all traces of life in our system. Let's not even get started on pandemics.

As if awareness of our own mortality hasn't given us enough to fret about, we are also capable of imagining our own species' extinction. Once we do that, though, are we not ethically bound to do something about it?

Chris Mason, a geneticist at Cornell University in New York, thinks so. In *The Next 500 Years*, he writes: "Engineering is humanity's innate duty, needed to ensure the survival of life." And not just human life – Mason is out to ensure the cosmic future of all living things, including species that are currently extinct.

He isn't the first to think this way, but his book arrives at a fascinating moment in the history of technology, when we may, after all, be able to avert previously unavoidable catastrophes.

Mason's 500-year plan for our future involves re-engineering human and other genomes so that we can tolerate the extreme environments of other worlds. Our ultimate goal, he says, should be to settle new solar systems.

Spreading humanity to the stars would hedge our bets nicely, only we currently lack the tools to survive the trip, never mind the stay. That is where Mason comes in. In 2015, he became the principal investigator on NASA's Twins Study, an analysis of the health of identical twins Scott and Mark Kelly during a 340-day period when Scott was in space and Mark was on Earth.

Mason explains how the study informed our understanding of the human biome, and how a programme once narrowly focused on human genetics now extends to bacteria and viruses. He even describes how tools like CRISPR and its successors may enable us to address the risks of space flight (exposure to cosmic radiation is considered the most serious) and protect the health of settlers on the moon, on Mars and even on Saturn's moon Titan.

> "Spreading humanity to the stars would hedge our bets nicely, only we currently lack the tools to survive the trip"

Outside his specialism, Mason has some fun (a photosynthesising human would need skin flaps the size of two tennis courts – so now you know) then flounders slightly, reaching for familiar narratives to hold his sprawling vision together.

More informed readers may start to lose interest in the later chapters. The role of spectroscopy in the detection of exoplanets is certainly relevant, but in a work of this gargantuan breadth, I wonder if it needed rehearsing. And will readers of a book like this really need reminding of Frank Drake's equation regarding the likelihood of extraterrestrial civilisations?

Uneven as it is, Mason's book is a genuine, timely and engaging addition to a 1000-year-old Western tradition, grounded in religious expectations and a quest for transcendence and salvation. Visionaries from Isaac Newton to Joseph Priestley to space pioneer Konstantin Tsiolkovsky have all expounded on the tenets that underpin Mason's account: the apocalypse is imminent, but, by increasing human knowledge, we may recover the paradise we enjoyed before the flood.

Masonic beliefs follow the same pattern. Significantly, many famous NASA astronauts, including John Glenn and Buzz Aldrin, were Freemasons. This Mason puts a new layer of flesh on what have, so far, been some ardent but very sketchy dreams.

While a proud child of his engineering culture, Mason is no dupe and no Frankenstein. He explores the major risks of genetic tinkering, entertains the pertinent counterarguments, knows where 19th-century eugenics led and understands the value of biological and neurological diversity. His deepest hope isn't to see his plans realised, more that we continue to make, test and remake them, for the sake of all life. ▮

A 500-year plan for humanity
More from Chris Mason in an online event in July
newscientist.com/science-events

Unwanted cargo

A space crew faces an impossible choice when an unplanned passenger compromises everyone on board, finds **Linda Marric**

Film

Stowaway
Joe Penna and Ryan Morrison
Streaming on Netflix

EVERYTHING seems to be going well for the three-person crew of a ship on a two-year voyage to Mars and back. For her final mission, commander Marina Barnett (Toni Collette) has been tasked with transporting biologist David Kim (Daniel Dae Kim) and medical researcher Zoe Levenson (Anna Kendrick) to their new base on Mars where they are expected to conduct some valuable research.

Things take a turn for the unexpected when the crew discovers an interloper on board a few hours after launch. The man in question is Michael Adams (Shamier Anderson), a launch support technician who found himself trapped inside the ship just before take off.

***Stowaway*, a Netflix-produced space thriller from writer-director Joe Penna and Ryan Morrison, tells the story of this crew, which soon faces an impossible choice.**

Injured and visibly shaken by his ordeal, Michael begs the commander to turn the ship around and take him back home, where he is the sole guardian for his younger sister, but the commander won't budge. Michael instead has to accept that he is on board for the long haul.

On closer inspection, it later transpires that Michael had accidentally damaged the ship's vital carbon dioxide scrubber. The result is that, even if they cultivate the oxygen-producing algae destined for Mars early, the ship can only sustain enough oxygen for three people. With little chance of making it back to Earth or to Mars as a foursome, a decision must be made about what to do with Michael, but not everyone agrees with what is being suggested.

Penna and Morrison's film is a deeply compelling, believable and handsomely acted thriller. With some nail-biting dramatic moments and an inspired "what if" idea, *Stowaway* manages to avoid the pitfalls that similarly themed productions have suffered from in the past.

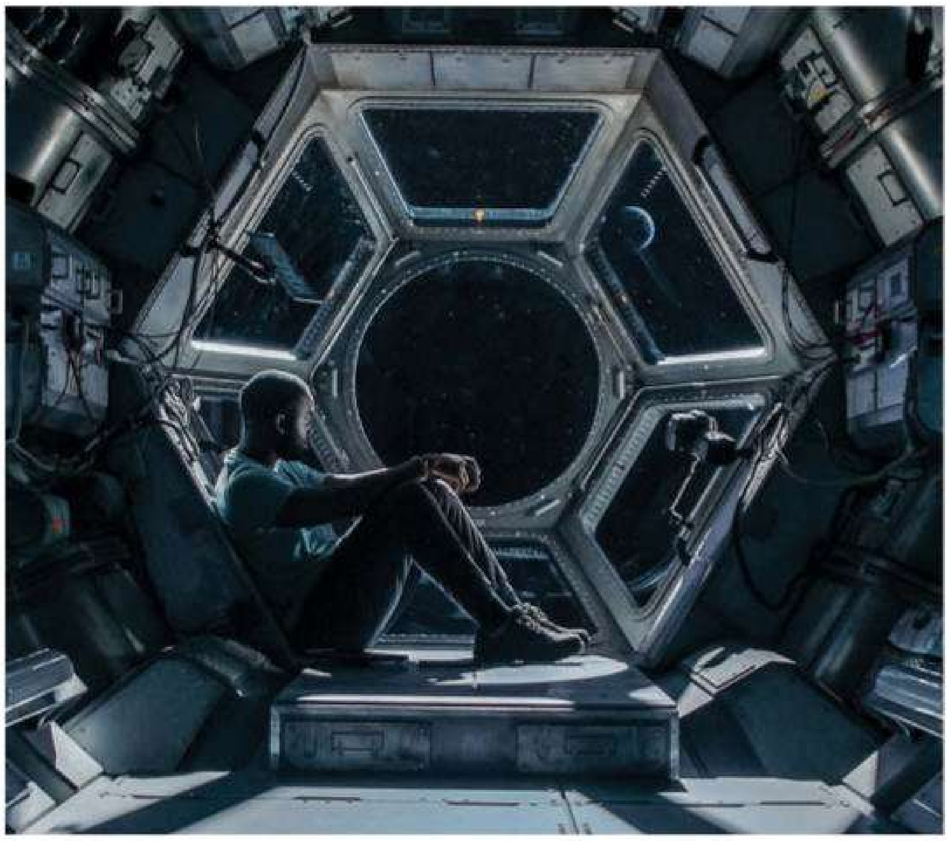
> **"Things take a turn for the unexpected when the crew discovers an interloper on board a few hours after launch"**

And while the obligatory suspenseful spacewalks are perhaps less impressive than those in Alfonso Cuarón's *Gravity* or more recently George Clooney's *The Midnight Sky*, there is still a commendable philosophical thread running through the film's narrative that makes up for any other shortcomings.

Questions about sacrifice and the value of a life are asked at regular intervals, but even though they are never fully answered, there is a sense that Penna and Morrison have examined the film's brilliantly nuanced premise from every possible angle and have, in turn, given us an inspired narrative that is bound to provoke much discussion and debate.

The film also manages to ask some pertinent questions around the value of scientific progress and whether it is important to pursue research to the detriment of human life. Furthermore, we are asked to decide who has the right to be saved when things go wrong and whether any human is, in fact, disposable.

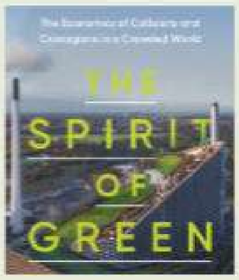
Overall, *Stowaway* is slow-paced and undeniably claustrophobic, but at the heart of it, there is a genuinely intriguing philosophical idea that is not only engaging, but also fantastically thought out. ■



Stowaway technician Michael Adams (Shamier Anderson) ponders the long trip to Mars

NETFLIX

Don't miss

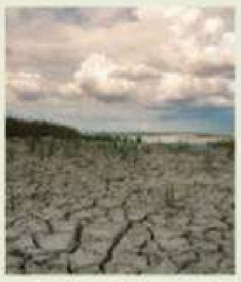


Read

The Spirit of Green is Nobel prize-winning economist William D. Nordhaus's account of how green thinking can help overcome today's challenges, from climate change to corporate wrongdoing, without sacrificing prosperity.

Visit

Halo, at Brighton Festival in the UK, is an intricate multisensory installation that lets you experience conditions shortly after the big bang. Created by artist duo Semiconductor, it is driven by data collected at the CERN particle physics lab. From 19 May to 4 June.



Listen

Princeton University Press Ideas Podcast interviews Lucas Bessire in an episode called "The water crisis on the High Plains". Bessire talks about his new book, *Running Out*, and the imminent depletion of a vital aquifer.

T-B: PRINCETON UNIVERSITY PRESS; CLAUDIA MARCELLONI, CERN; TONI MARINOV/ALAMY

The sci-fi column

Psychic survival *Shards of Earth* is the first part of a compelling new space opera, featuring starship battles, godlike entities the size of moons and a hidden dimension with freakish psychological properties, says **Clare Wilson**

Clare Wilson is a medical reporter at *New Scientist* and a lifelong fan of sci-fi @ClareWilsonMed

GRANDEDUC/ALAMY

The price of piloting through the mysterious unspace is horribly high

Book

Shards of Earth

Adrian Tchaikovsky

Tor (out on 27 May)

MOST tales of clashing alien civilisations require some mind-blowing science to let ships cross the vast distances between stars. This might involve shortcuts through hidden dimensions, *Star Trek*'s powerful warp drives or, as in Douglas Adams's satirical *Hitchhiker's Guide to the Galaxy* series, the new laws of mathematics invoked when you drunkenly try to settle a bill after a long meal in an Italian restaurant.

Usually, the secrets behind space travel are a minor detail. However, in Adrian Tchaikovsky's latest work, *Shards of Earth*, the mechanism – in this case a hidden dimension – has freakish psychological effects that are integral to the plot.

Tchaikovsky was awarded the 2016 Arthur C. Clarke prize for *Children of Time*, which won praise for its sympathetic portrayal of a race of oddly endearing spiders.

Shards of Earth is more traditional sci-fi fare: a rip-roaring space opera featuring starship battles, genetically enhanced superhumans and multiple weird and wonderful aliens. Some trade with humans, others try to enslave them, while the mysterious and menacing Architects seem to barely notice humans as they go about destroying their planets.

Architects are entities the size of moons and their godlike abilities mean they can reshape space and matter as they see fit.

> **"The mysterious Architects barely notice humans as they go about destroying their planets"**

For unknown reasons, their favourite pastime seems to be turning other people's spaceships – or entire worlds – into filigree sculptures that are wholly incompatible with life.

In this universe, ships move between the stars by popping in and out of a weird realm called unspace. Piloting through it can be mastered only by humans who have had sinister things done to their minds in a programme of chemotherapy and psychosurgery that few can survive.

Anyone capable of piloting ships in this manner, such as one of the book's protagonists, Idris Telemmier, becomes immensely valuable and in constant danger of being kidnapped and put to work by gangsters or space fleets.

As the book opens, Telemmier has been trying to stay under the radar, working in a team of misfits who salvage wrecked spaceships. But the strange, psychic powers of unspace pilots happen to be one of the few ways of communicating telepathically with the Architects. As war with the Architects looms, Telemmier sees his chance of living a peaceful life dwindle.

To add to the troubles, piloting in unspace isn't good for the human brain: it reacts by creating the sensation of a predatory presence that can send people insane. Passengers on ships travelling between the stars can enter artificial sleep, but pilots must stay awake. Telemmier hasn't slept in 47 years, and sometimes it shows.

Tchaikovsky writes in convincing detail about the effects of unspace. One of the book's most gripping passages comes when a non-psychic crew mate of Telemmier has to enter this realm awake due to a technical hitch and we accompany her descent into near-madness.

My one complaint is that the book falls into the sci-fi trap of being occasionally hard to follow, with so many alien species, worlds and characters to track. But this wasn't a deal-breaker and things improved once I discovered the glossary and timeline at the back of the book. *Shards of Earth* is the first part of a trilogy and I can't wait to read the next one. ▮

Clare also recommends...

Short story

Difficult Times

Adrian Tchaikovsky

If you are a Tchaikovsky fan, check out this short story he wrote for New Scientist *(19/26 December 2020, p 40), about why a failing fringe electro band may have plugged into a cosmic secret.*

Design and artwork by VisualSense.com

> “The lessons are very clear, stimulating, fun and very helpful ... The terrific variety of activities we’ve covered has inspired a lot of pleasurable meanderings at the keys.”
>
> Piano Sanctuary online student

Piano tuition for adults of all ages and abilities

- * Creative, exciting new method for fast-track progress
- * Personalised online short courses - book now for immediate start
- * Idyllic Retreats at Leiston Abbey, Suffolk, throughout the year

pianosanctuary.co.uk
hello@pianosanctuary.co.uk
01728 831354

Piano Sanctuary

Operated by Pro Corda Trust, a registered charity No.116213

The idea that the quantum world isn’t as random as it seems is taboo for many physicists. But could it finally make sense of quantum theory, asks **Michael Brooks**

Is everything predetermined?

PETE REYNOLDS

“I’VE never worked on anything so unpopular!” Sabine Hossenfelder, a theoretical physicist at the Frankfurt Institute for Advanced Studies in Germany, laughs as she says it, but she is clearly frustrated.

The idea she is exploring has to do with the biggest mystery in quantum theory, namely what happens when the fuzzy, undecided quantum realm is distilled into something definite, something we would experience as real. Are the results of this genesis entirely random, as the theory suggests?

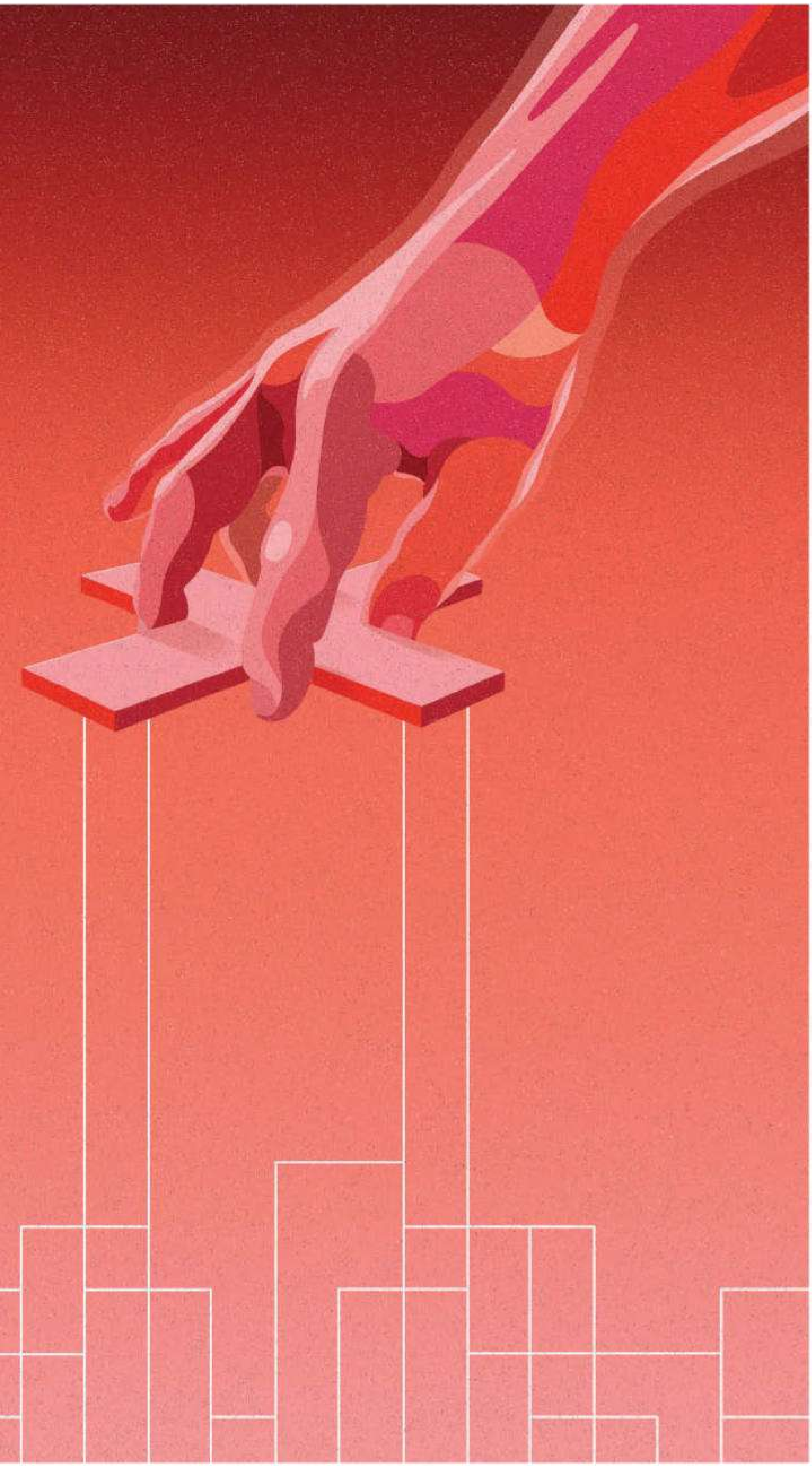
Albert Einstein was in no doubt: God, he argued, doesn’t play dice with the universe. Hossenfelder is inclined to agree. Now, she and a handful of other physicists are stoking controversy by attempting to revive a non-random, “deterministic” idea where effects always have a cause. The strangeness of quantum mechanics, they say, only arises because we have been working with a limited view of the quantum world.

The stakes are high. Superdeterminism, as this idea is known, wouldn’t only make sense of quantum theory a century after it was conceived. It could also provide the key to uniting quantum theory with relativity to create the final theory of the universe. Hossenfelder and her colleagues aren’t exactly being cheered on from the sidelines, however. Many theorists are adamant that superdeterminism is the most dangerous idea in physics. Take its implications seriously, they argue, and you undermine the whole edifice of science.

So what is the answer? Does superdeterminism deserve its bad reputation or, in the absence of a better solution, do we have little choice but to give it a chance?

Quantum theory describes the behaviour of matter at its most basic, the atoms and their constituent particles. It was conceived to make sense of the observed behaviour of atoms, and resulted in physicists claiming that particles behave like waves and can appear to be in several different states at once, known as being in a superposition. The idea is that only when we observe those particles directly do they assume definite properties.

Erwin Schrödinger came up with an equation to capture the fuzziness of the quantum realm, showing that it could be represented by a mathematical entity later



called a wave function. This gives the probability that a quantum object will manifest as a particular state or place upon measurement. But it can't say for certain.

In fact, we only get agreement between theory and experiment when we average out the results of lots of measurements of identical quantum objects. That leads to the assumption that each individual outcome occurs at random, and thus that, at the most fundamental level we know, the universe is indeterministic – governed by chance.

That is hard to swallow for many people because we experience a world in which effects always have a cause. Some have tried to fix the situation by suggesting that the simultaneous different states of an atom in superposition are a reflection of different realities occurring in separate universes. Or by saying that the atoms just don't have any properties and don't really exist when they aren't being observed.

But none of these interpretations make sense to Hossenfelder. All of them contain contradictions, she says, which is why she is working to explore superdeterminism.

Broadly speaking, this is the idea that the outcome of any measurement is due to factors involved in the measurement, such as the measuring apparatus and its settings. What we see is determined by all these factors, including, perhaps, factors that are hidden from us.

To get to grips with the concept, first you have to understand an idea put forward by physicist John Bell in the 1980s. Bell proposed a scheme for testing whether there was merit to another of Einstein's reservations about quantum theory, this time about "spooky action at a distance", as Einstein dubbed it, in which measurements of one particle seem to influence the outcome of measurements of another, spatially distant particle.

Bell's scheme concerned the statistical outcome of a series of measurements on two particles with quantum properties that are "entangled" with each other because of some interaction in the past. He showed that if these non-local correlations aren't real, then there is a minimum probability with which you should get a particular outcome, such as the same ›

"The resulting theory could have all the consequences of quantum mechanics, but none of the weirdness"

result from both measurements. It can be greater than or equal to this value, but it can't be lower. In mathematical terms, it is known as an inequality. If you find you are getting the outcome of interest less often than you would expect, "Bell's inequality" is being violated – and you know the results are being skewed by a non-local correlation between your particles.

Forbidden choices

Experiments have demonstrated that it is possible to violate Bell's inequality. This seems to prove that the spooky action is real, in spite of Einstein's objections. But the proof depends on an assumption about the measurement.

Specifically, Hossenfelder questions the assumption that the experimenter is entirely free to choose the "basis" of any given measurement. Given a collection of gloves, say, you might choose to compare them on the basis of their size, handedness or colour – or a combination of these. But what if certain measurement choices are forbidden by some as-yet-unknown law of physics? What if, for instance, the universe won't let you measure the colour of a right-hand glove independently of measuring its size? If that were the case, you might get a strange result when you tried to do it. And if you didn't know about that law, you might conclude that some fundamental weirdness exists in the world of gloves.

The idea that nature forbids certain choices might seem far-fetched, but quantum theory itself was built on a far-fetched restriction. Max Planck only discovered it through what he called "an act of desperation": conjecturing that atomic stuff comes in definable lumps of energy, with certain energies forbidden. What's more, we have since discovered that atomic structures such as two electrons can't occupy the same quantum state inside an atom, which is known as the Pauli exclusion principle. "In that case, no one asks, 'how is it that I can't put these electrons in the state that I want to?'" says Hossenfelder. "You just say it's a law of nature: that's just how it is."

To move the idea along, Hossenfelder is creating a model of reality that forbids certain combinations of quantum states from existing. She is hoping that the resulting idea will have all the consequences of quantum mechanics, but none of the weirdness.

Critics have invoked the film *Back to the Future* to argue against superdeterminism

UNIVERSAL PICTURES/PHOTO 12/ALAMY

She isn't the first to lean in this direction. Physics Nobel laureate Gerard 't Hooft at Utrecht University in the Netherlands has proposed something along these lines. And Tim Palmer, a physicist at the University of Oxford, is joining their ranks. Palmer used to work at the European Centre for Medium-Range Weather Forecasts, and his experience with the physics of chaotic systems like weather has led him to formulate a chaos-based superdeterminism idea that he thinks might explain the quantum world.

In chaos theory, systems such as weather patterns evolve in a way that is extremely sensitive to their initial conditions. Tiny changes in the set-up lead to huge divergences in the later characteristics of the system. At the same time, some chaotic systems will always converge towards a particular set of characteristics. This can be captured in a mathematical entity called a chaotic "attractor", which maps their movement through all the possible states towards these almost inevitable outcomes. The attractor has a curious, often-ignored property, however. In any chaotic system, there are states and situations that are just off-limits. The attractor's blank space defines which states are impossible to access.

Palmer has been investigating what it would mean if our universe were subject to the same constraints. "I imagined that the universe is a chaotic system evolving on its own attractor," he says. Then he pictured conducting a Bell experiment in this chaotic universe. The experimenters would still make choices about the measurement basis, but Palmer thinks that certain combinations of quantum states could be unattainable, implying that some experimental choices defy the laws of physics. "These gaps in state space, the places the system is not allowed to go, give you the wiggle room you need to be able to violate Bell's inequality without having to fall back on indeterminacy or non-locality," says Palmer.

He plans to put his ideas to the test, starting

LUIS JOU GARCIA/GETTY IMAGES

Superdeterminism suggests that in the quantum realm, some choices are off limits

with an experiment that has to do with the number of quantum objects that can be entangled together. In standard quantum theory, there is no limit, but in Palmer's scheme that number is finite. "After a certain number of entanglements, you'll just go back to classical correlations," he says. In February, with Jonte Hance and John Rarity at the University of Bristol, UK, Palmer published a range of experimental designs that are aimed at finding the limit, if it exists.

Hossenfelder is even further along. Her design involves performing a set of repeated measurements on a quantum system. "A general prediction of superdeterminism is that the outcome of measurements is actually determined, not random. So you test it by checking whether quantum measurements are really random," says Hossenfelder.

In her design, each initial set-up should be an exact copy, as far as is possible, of the one before. If the universe is ultimately deterministic, the results should be more or less identical. But if probabilistic quantum mechanics really is fundamental, there would be easily discernible changes in the outcome of each run.

That is harder than it sounds: you have to make sure you don't introduce randomness through the measurement device, so the smaller it is and the lower the temperature it operates at, the better. "You also have to do the measurements in as fast a sequence as possible because the more time passes, the more likely it is that something wiggles," says Hossenfelder.

A vast conspiracy?

The good news is that Siddharth Ghosh at the University of Cambridge has just the sort of set-up that Hossenfelder needs. Ghosh operates nano-sensors that can detect the presence of electrically charged particles and capture information about how similar they are to each other, or whether their captured properties vary at random. He plans to start setting up the experiment in the coming months.

All of which sounds exciting. And yet a large number of philosophers and physicists scoff at the prospect, insisting that we don't need to do experiments to rule out superdeterminism. Howard Wiseman at Griffith University in Queensland, Australia, pretty much sums up the objections when he says the idea would imply there is a "fine-tuning" conspiracy behind the laws of physics, meaning you have to input initial conditions by hand and choose them very precisely to make sense of observations. And that's just for starters. Wiseman adds that superdeterminism would also undermine the notion of human free will and make the whole idea of doing science pointless. "I'm not a fan," he says.

This last point comes from the fact that superdeterminism violates something known to philosophers of science as "statistical independence". This is the idea that tweaking the input to an experiment shouldn't change anything in the equipment set-up to detect the output. The free will problem arises because, in the Bell test, the experimenter has to be able to set the experiment up however they want to. Superdeterminism says this isn't possible because there are hidden constraints.

But Wiseman thinks the fine-tuning argument is the most persuasive. He points out that experimenters have made deliberately ridiculous, random choices when performing Bell experiments – choosing sequences of binary digits from a digitised version of the 1985 movie *Back to the Future* to create the measurement settings, for example. Since superdeterminism explains Bell experiments through correlations between hidden variables in the quantum particles and the measurement settings, that would imply that the series of events and choices in the film's production are correlated with the actions of the physicists carrying out the experiment.

"According to superdeterminism, the explanation for these particular Bell correlations is that it is impossible to have a universe in which the hidden variables in the experimental photons are the same, but Michael J. Fox's smile was 1 millimetre wider in one frame of *Back to the Future*," says Wiseman. "It's the most bizarrely fine-tuned theory imaginable. The whole thing is a vast conspiracy: an insanely complicated universe with unimaginably fine-tuned initial conditions."

Palmer rejects this argument. "It is most certainly not the case that superdeterminism says that there is any conspiracy," he says. The problem, he says, is that people see fine-tuning because they are applying the wrong kind of mathematics. Physicists assume that the fundamentals of the universe evolve in a linear fashion, but they might well be chaotic, says Palmer. In which case, the linear equations we have won't work.

In any case, the choice of *Back to the Future* was itself curious. That is because, according to Huw Price, a philosopher at the University ›

If quantum randomness is an illusion, we may be able to make more robust quantum computers

XINHUA/ALAMY

of Cambridge, backwards-in-time causation is the one thing that can make superdeterminism plausible. Price argues that superdeterminism works if you take the "block universe" perspective of Einstein's special theory of relativity, where past, present and future all co-exist in a big four-dimensional grid we call space-time.

> "If there is backwards-in-time causation, science and human free will can be rescued"

In this scheme, time doesn't run in any one direction. Time's arrow isn't fundamental to relativity – or to quantum theory, for that matter. And that means tweaking a detector's settings to determine the properties of two entangled particles in a particular way can influence the properties those particles gained at what we would call an earlier time. "The setting that we chose has an influence on the particle all the way back to when it was first formed in some event that produced two particles," says Price.

He believes this perspective has two advantages. First, it doesn't require that the universe was set up in some precise, finely tuned way that gives the experiment its outcome. Second, it doesn't undermine science and human free will. Emily Adlam, a philosopher of physics affiliated with the independent Basic Research Community for Physics, says she is willing to consider this idea. "An approach where the laws of nature apply all at once to the whole of history gives much less reason for concern."

Wiseman remains unconvinced. It is all just too vague, he says. People have been suggesting that some kind of "retrocausality" might resolve our problems with quantum theory for nearly 100 years, he points out, but no one has ever embedded an idea that works this way into Einstein's space-time.

And what would be the point? "I don't see the motivation for wanting to deny the conclusion of Bell's theorem," says James Ladyman, a philosopher at the University of Bristol, UK. It isn't the end of the world to accept the existence of a non-local phenomenon like entanglement, even if it does go against our metaphysical presuppositions.

The proponents of superdeterminism think there is a lot to be gained, however. For a start, it might open the door to new kinds of technology, says Hossenfelder. The limits to how well we can make measurements come from the noise that has its roots in quantum randomness. If the apparent randomness is actually the result of controllable processes, perhaps we could push down the quantum noise. "I think this would be important for quantum computing – the major issue that they have is the noise," says Hossenfelder.

For Palmer, the benefits might lie in the quest to unite quantum theory with relativity to create a theory of quantum gravity. The usual approach is to modify relativity and leave the quantum stuff alone, but Palmer thinks that superdeterminism suggests this might be a mistake. "It's going to require a lot more give from the quantum side than from the relativity side," he says.

There is no agreement in sight, and progress is slow because there are so few people working on superdeterminism. Nonetheless, their proposal for answering the riddle of quantum theory is worth exploring, says Adlam. "I wouldn't say superdeterminism is my preferred route, but I think it's definitely reasonable, and it deserves a lot more attention than it has received." ▮

Michael Brooks is a *New Scientist* consultant and author of *The Quantum Astrologer's Handbook* (Scribe)

Algal blooms, like this one in the Barents Sea, may look beautiful, but they can choke other marine species

EUROPEAN SPACE AGENCY

The godfather of pollution

The damage wrought by nitrogen fouling our land, water and air is terrible and underappreciated. At last, the global fightback is starting, says **Andrew Zaleski**

THERE is an invisible gas in Earth's atmosphere that is feeding an environmental crisis. The damage gets worse every year. If things are left unchecked, we are heading for a global disaster. And here is the most worrying thing about this gas: it isn't carbon dioxide.

Nitrogen is normally thought of as inoffensive stuff; after all, this colourless substance makes up 78 per cent of Earth's atmosphere. When you feel a refreshing breeze on your cheeks, it is mostly nitrogen molecules swishing past. Our ecosystems naturally cycle nitrogen from the air in and out of our soils, where it forms an essential nutrient for plants. The trouble is, this cycle is now dangerously out of whack because of human activity. The result is nitrogen in harmful forms swamping the wider environment.

Some of the effects of this crisis have been obvious for ages. We have long known, for instance, that pollution from nitrogen-bearing compounds prompts algal blooms that choke waterways. But other effects are now coming ›

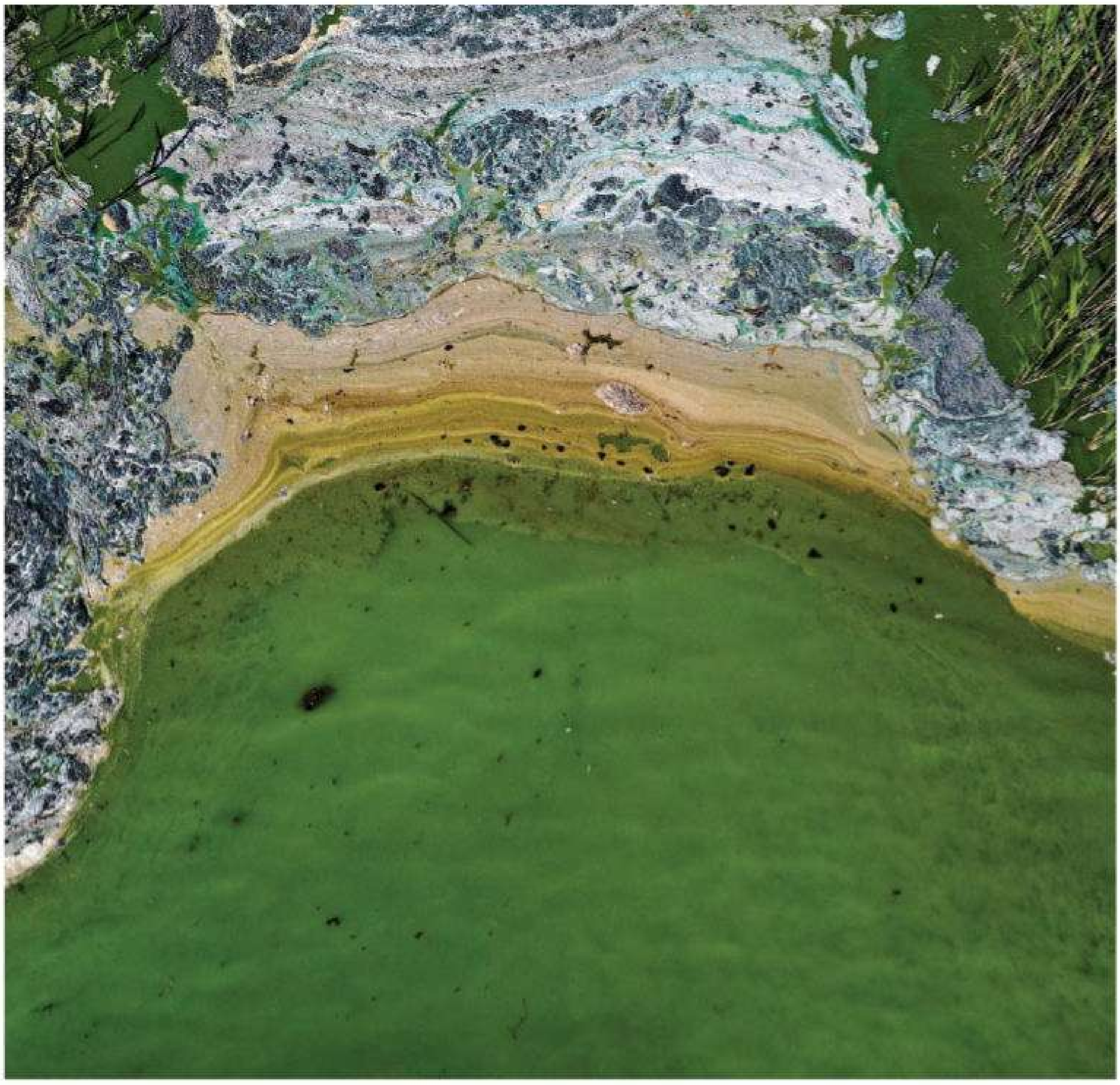
Five ways nitrogen is harming our planet

1. Ocean dead zones

Rain can wash nitrates into watercourses and oceans. This nitrogen-based pollution feeds algal blooms that suck up oxygen as they decompose, choking aquatic life. The result is a watery "dead zone", of which there are more than 400 in the world's oceans, including a huge one in the Gulf of Mexico.

2. Air pollution

Cars and power plants emit nitrogen oxides, which are one of the principal precursors to a type of air pollution called particulate matter. These tiny particles can be breathed into our lungs, where they cause tissue damage associated with a range of health problems.



IBL/SHUTTERSTOCK

into focus too, like the way nitrogen pollution is killing peat bogs. Compounds of nitrogen are also damaging the delicate balance of the atmosphere.

A United Nations panel set up to assess the problem has revealed just how bad things have become. In fact, nitrogen pollution is one of the most dire crises we face. Fortunately, there are ways that we can dig ourselves out of this hole – but they will involve wholesale changes to how we grow our crops.

All life on Earth depends on nitrogen. Most of the crucial chemical components of our bodies, from the proteins in our nails to the DNA at the heart of every cell, incorporate this element. But even though nitrogen gas is all around us, it isn't useful as a raw material for living things in that form. Nitrogen molecules in the atmosphere consist of two nitrogen atoms joined by an extremely strong triple bond, making it tough to chemically manipulate.

Life requires its nitrogen in a more reactive form, sandwiched into compounds with weaker bonds. Animals get these compounds in their food, but they initially enter the food chain on land through two main natural processes. The first involves bacteria living in association with the roots of leguminous plants such as peas. These microorganisms take in nitrogen molecules from the air and use special biochemical machinery to prise apart that triple bond. Then they combine the resulting nitrogen atoms with hydrogen to form ammonia in a process called nitrogen fixation. Other bacteria then convert the ammonia into nitrate ions, which plants can absorb. The only other natural process with the necessary heft to fix nitrogen is a lightning bolt.

This is one half of the nitrogen cycle. Meanwhile, other bacteria carry out the process in reverse, breaking down nitrogen-

> **"Nitrogen is normally thought of as inoffensive; after all, it makes up 78 per cent of the atmosphere"**

QILAI SHEN/PANOS PICTURES

Nitrogen-based pollution degrades the environment in various ways. It can contribute to algal blooms in Sweden (far left), smog in Baoding, China (left), and soil with higher acidity (below left)

3. Soil acidification

The same nitrate that can sneak into waterways can also pull key nutrients out of the soil, including magnesium and calcium. This can make soil too acidic, such that plants are unable to take up nutrients properly.

SJ IMAGES/ALAMY

containing compounds in dead plants and animals and releasing nitrogen gas back to the atmosphere. In a world without human meddling, it is thought that the cycle should roughly balance out.

For centuries, farmers have observed that plants generally tend to grow better if the soil has been prepared with lots of nutrient-rich manure. So they forked in this natural fertiliser and grew legumes, with their symbiotic nitrogen-fixing bacteria, in rotation with other crops.

The trouble began in the early 1900s, when the German scientists Fritz Haber and Carl Bosch devised an industrial means of plucking nitrogen gas from the air and converting it to ammonia. Modern synthetic fertiliser was born. This was originally heralded as a success story because of all the extra food it helped us grow. Today, adding nitrogen-based fertilisers to poor soil allows us to feed 2 billion people who would otherwise go hungry.

But the Haber process, as the chemistry is called, has big downsides when carried out on industrial scales. The conditions required are punishing – a temperature of 450°C and a pressure about 200 times that at Earth's surface. This swallows huge amounts of power: worldwide, the Haber process is responsible for 1 per cent of human CO_2 emissions, about the same as the entire UK.

Worse, all the extra ammonia being produced has tipped the nitrogen cycle wildly out of balance. To see just how bad it is, it helps to think in terms of a concept called planetary boundaries. The idea is that nine crucial environmental systems – for example, fresh water and the ozone layer – can't be degraded too much before presenting an existential risk to humanity. The nitrogen cycle is one of these systems and the best estimates suggest there should be no more than 62 million tonnes of nitrogen a year fixed on land to remain within the safe boundary. Admittedly, there is a good deal of uncertainty about how much nitrogen is fixed by nature. Still, it is clear that we have smashed through the planetary boundary: today, at least about 300 million tonnes of nitrogen are fixed each year through both natural and artificial processes (see diagram, page 45). "We've completely disrupted the balance of where these nutrients sit and what life forms they are accessible to," says biogeochemist Penny Johnes at the University of Bristol, UK.

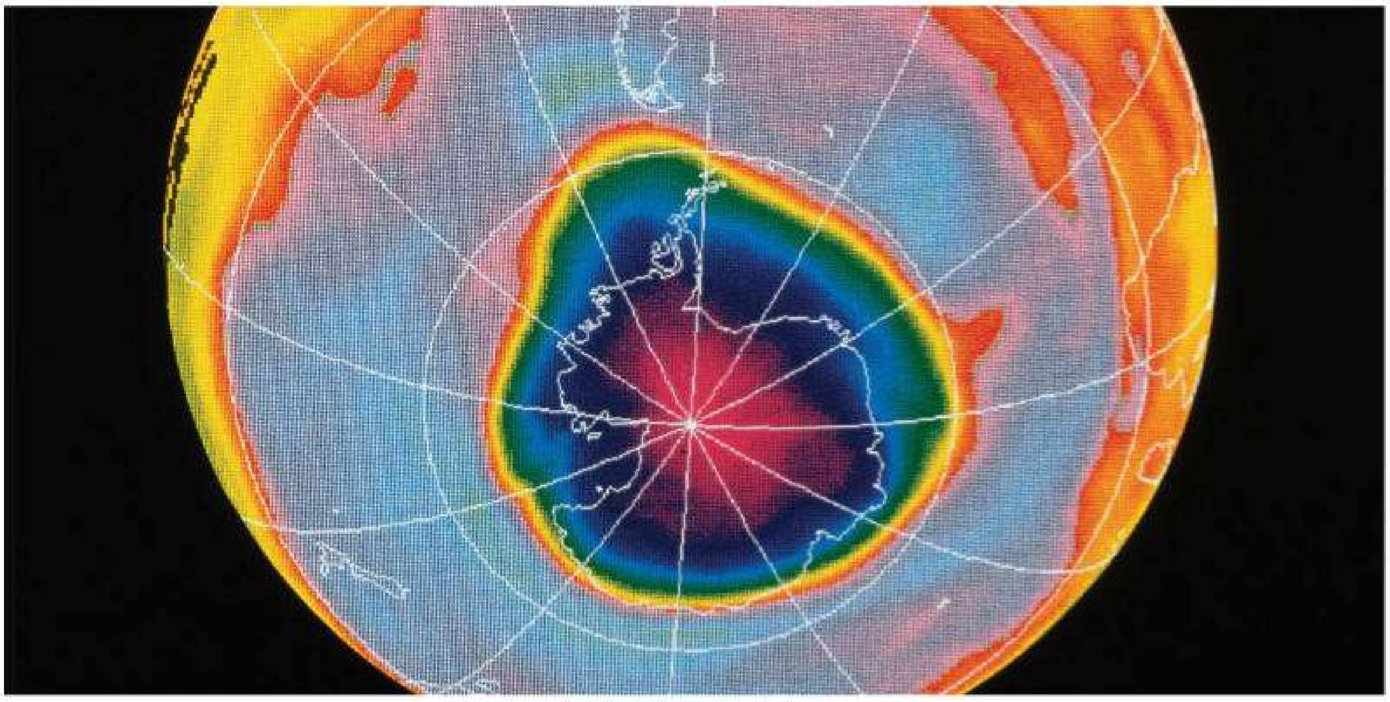
Need a fix

Few know this better than Mark Sutton at the UK Centre for Ecology and Hydrology, who has been studying nitrogen pollution for decades. In 2011, the United Nations Environment Programme asked him to undertake the first global assessment of the problem, to determine how bad it was, what to expect in future and how to fix it. A few years later, Sutton became the head of a UN-backed project aiming to develop an International Nitrogen Management System (INMS).

The aim was to do for nitrogen what the Intergovernmental Panel on Climate Change (IPCC) had done for CO_2. Sutton and his team are drawing on the existing research to chart the full extent of well-documented problems like fertiliser pollution being washed into our oceans. They have also highlighted some previously unknown issues (see: "Five ways nitrogen is harming our planet", left). "The INMS doesn't have to prove the existence of nitrogen pollution," says Sutton. "Rather, it's got to say how we get the world scientific community to work together."

The IPCC has set a recognised goal of limiting global warming to 1.5°C by 2100 compared with pre-industrial temperatures. Sutton and his team wanted a similar rallying call for nitrogen use, but knew it would be politically tricky. He recalls one meeting at New York University in 2018, where he sat with a handful of nitrogen experts discussing what target they should set.

They realised that asking the world to cut nitrogen use in agriculture would meet a lot of resistance, notably from the powerful fertiliser industry. In the end, the scientists decided to call for nitrogen waste to be cut instead – after all, up to 58 per cent of the nitrogen in fertiliser isn't taken up by crops. It was an easier sell, they thought; who could object to cutting waste? And it was much needed. Research by ›



NASA/SCIENCE PHOTO LIBRARY

SCENICIRELAND.COM/CHRISTOPHER HILL PHOTOGRAPHIC/ALAMY

4. Ozone depletion

Excess nitrate can be converted by bacteria into nitrous oxide gas. At high altitudes, this reacts with ultraviolet light and eats away at the ozone layer that shields us from UV rays. The damage is tough to undo, because nitrous oxide has a lifespan of 120 years.

5. Alkaline air

Rising levels of ammonia pollution are decreasing the acidity of the air. Certain habitats, such as peat bogs, rely on the air being slightly acidic. In Northern Ireland, this problem is causing the degradation of sphagnum peat moss bogs, a major store of carbon dioxide.

Nitrogen pollution can damage the ozone layer (a map of which is shown, top) and kill peat bogs in Northern Ireland (bottom)

Xin Zhang, now at the University of Maryland, and her colleagues shows that nitrogen use efficiency has fallen from 50 per cent in 1961 to 42 per cent today.

In October 2019, the UN held a meeting in Colombo, Sri Lanka, to discuss the nitrogen problem. Just beforehand, Sutton and 150 colleagues wrote to the UN secretary-general urging that their idea for a waste-cutting target was taken up.

It worked. The meeting adopted the Colombo Declaration, a road map for halving nitrogen waste by 2030. But with only 14 nations so far signed up, nitrogen remains a fledgling cause on the international stage. "It feels like the Paris Agreement is a massive 500-year oak tree and the Colombo Declaration is a little sapling," says Sutton.

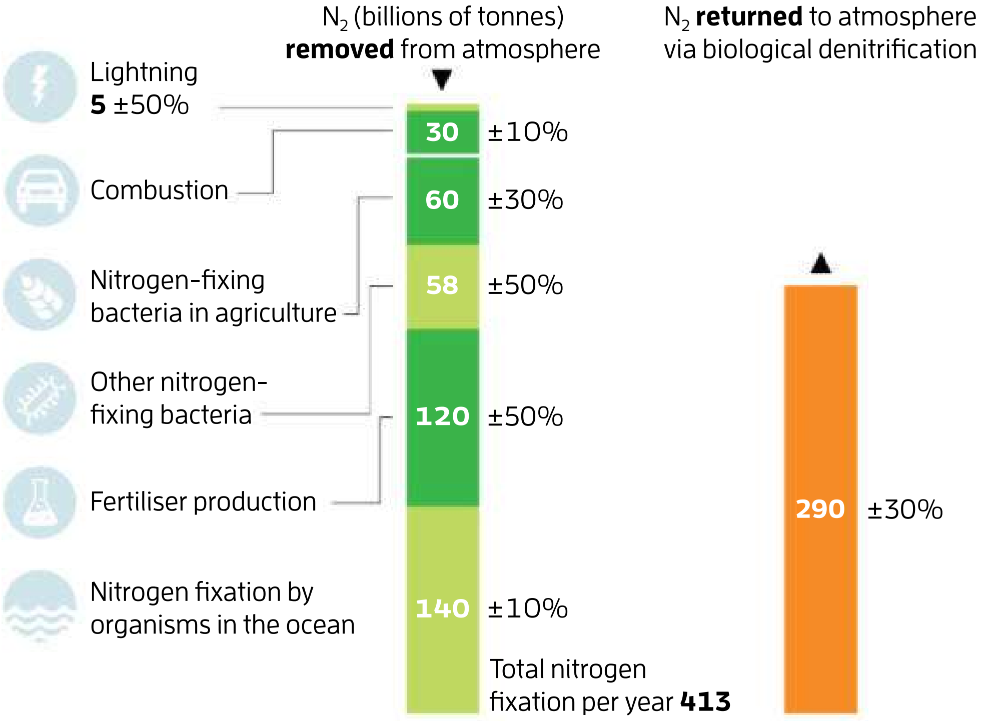
> **"If we don't deal with nitrogen, then dealing with any other environmental challenge gets a lot harder"**

That isn't to say that climate change and nitrogen woes can be treated separately. Nitrogen pollution makes a swathe of other environmental problems worse, from pollution of drinking water to smog in cities. "If we don't deal with our nitrogen challenge, then dealing with pretty much any other environmental or human health challenge becomes significantly harder," says David Kanter, vice-chair of the International Nitrogen Initiative.

Take nitrous oxide, a gaseous by-product of denitrification carried out by soil bacteria. It is a greenhouse gas with about 300 times the warming impact of CO_2. More and more of it is being produced as we cram too much fertiliser into soils. Kanter says it simply won't

Nitrogen balance

The effects of humans on the nitrogen cycle mean that more nitrogen is being **removed from** the atmosphere each year than biological processes can **return to it**. In fact, human activities now outweigh the contribution of natural processes to nitrogen removal



SOURCE: DOI.ORG/10.1098/RSTB.2013.0164 AND MARK SUTTON

be possible to keep global warming below the IPCC's target of 1.5°C unless we do something about the nitrogen problem.

The way out of this mess begins with more intelligent management of fertilisers, by far the worst source of nitrogen pollution. Many farmers blanket their fields in fertiliser several times each growing season. This guarantees a great yield – but also a lot of nitrogen waste.

Better options already exist. Take the "smart nitrogen" fertiliser produced by businesses such as Nutrien. This comes as pellets of nitrogen encased in a polymer. Water leaches into the pellet, dissolves the nitrogen, which then seeps out gradually. This drip-feeds crops with a gradual supply, ensuring more gets absorbed and less runs into streams and so on.

Smart fertilisers are too expensive for most farmers, though, so some people are trying a low-tech equivalent called urea deep placement. Urea is a widely used and cheap nitrogen fertiliser. Its disadvantage is that once applied, it converts quickly to ammonia, creating such a build-up in the soil that ammonia gas escapes into the air.

The deep placement approach involves pushing granules of urea much further into the soil. This means that as urea turns into ammonia, it is already close to the roots and can be absorbed more readily. The International Fertilizer Development Center (IFDC), a global non-profit organisation, is conducting field trials of the strategy in countries including Ghana, India, Rwanda and Vietnam. Its researchers say the farmers in the trials are achieving nitrogen use efficiencies as high as 80 per cent. "The single most important thing that can enhance nutrient efficiency is controlling nitrogen," says Latha Nagarajan at the IFDC.

In wealthier places, a precision agriculture revolution promises even greater rewards. The idea is to use satellites, drones and remote sensors to get an up-to-the-minute picture of how crops and soils are faring. Does this corner of a field need an extra few grams of nitrogen? Would that stretch benefit from a little more water? Armed with this information, farmers can give each area exactly what it needs. In its ultimate realisation, robots fed with the data will do the farming while humans monitor from afar. This could be a game changer for nitrogen pollution, says Johnes.

One US company, PrecisionHawk, uses drones for overhead crop inspection. These have cameras to spot signs of blight or stress, an indication that more fertiliser is needed. The firm found that during the 2016 growing season, corn farmers using the system saved $4 a hectare on nitrogen fertiliser, meaning they were buying, and applying, less.

Perhaps the most ambitious solution is to reimagine what Haber and Bosch did all those years ago. Rather than extract nitrogen from the air in industrial quantities and slather it on fields, might we be able to convert nitrogen gas to ammonia where and when plants need it? A slew of biotech start-ups are starting to show that the answer is yes.

Root of the problem

Regular nitrogen fixing bacteria can only form symbiotic relationships with certain plants, like soya beans and legumes. But firms such as Pivot Bio in California are re-engineering these bacteria so they can nuzzle up to other crops, like wheat. Farmers spray the bacteria onto seeds before planting. After germination, the bacteria live symbiotically with plant roots and fix nitrogen into nutrients the roots can absorb. The firm carried out field trials of its system in 2018 across 47 US states, comparing the harvest from fields treated with their product and ordinary synthetic fertiliser. This showed that the bacteria-treated fields yielded about 480 kilograms more crop per hectare than those treated with ordinary fertiliser.

It is the symbiotic relationship between the bacteria and the roots that seems to be crucial. "Our data shows that the microbes are producing nitrogen right around the time that the corn is calling for that nitrogen," says Richard Broglie at Pivot Bio. The upshot is that the nitrogen gets absorbed from the soil more quickly, leaving less scope for it to escape into watercourses or the air. Several other US start-ups are working in this space, such as Joyn Bio in Boston and Intrinsyx Bio in Silicon Valley.

All these methods will go some way to reducing nitrogen pollution. The INMS is pushing 76 ideas for reducing nitrogen waste in a UN report published in December. But the mix of measures that will be most feasible and effective in any given place isn't yet known; the soil type and many other factors all make a difference. For now, it is up to farmers and governments to decide the best methods.

Meanwhile, Sutton is keen to rally support for the goal of halving nitrogen waste by 2030. Whether it is achievable will depend largely on the buy-in the INMS secures from countries by 2022, when its UN funding ends. By then, the hope is to have what Sutton calls the "godfather of pollution" firmly on the global agenda. ▮

Andrew Zaleski is a writer based near Washington DC

"I'm interested in whether we can create new senses"

Neuroscientist **David Eagleman** studies how our brains reconfigure themselves as we learn. He tells Clare Wilson how we can exploit this to create a different way of hearing – and maybe gain incredible new senses

ROCIO MONTOYA

WOULD you like to be hooked up to a device that lets you detect magnetic fields like a bird? How about sensing infrared light like a snake? Perhaps a feed of real-time stock market data into your mind is more your sort of thing. According to David Eagleman, a neuroscientist at Stanford University in California, it will soon be possible to make all this a reality.

He has already created technologies along these lines, including a wristwatch-like device called Buzz that translates sound into patterns of vibration on the skin. Interpreting those vibrations effectively gives deaf people who use it a new kind of hearing.

The inspiration for these ideas grew out of Eagleman's study of neuroplasticity, the brain's incredible ability to reforge itself in response to new experiences. In his latest book, *Livewired: The inside story of the ever-changing brain*, he examines just how the brain pulls off such wholesale changes and explores the extent to which we can harness this ability to learn new tricks.

Eagleman says neuroscientists still have a lot to learn about how the brain changes. Much of the focus has been on synapses, the connections between brain cells called neurons. But there are deeper and more mysterious ways in which the brain is changing all the time, he says, and we are guilty of overlooking them. As we learn more about the brain and begin to enhance it with new technology, we might gain some intriguing new abilities.

Clare Wilson: You study the way the brain changes in response to our experiences. How does it do that?

David Eagleman: When you learn that my name is David Eagleman there are physical changes in the structure of your brain. That's what lets you remember who I am. We often say the brain has plasticity, meaning it can be moulded like plastic. But I feel the term plasticity isn't big enough to capture the way that the whole system is moving. Instead, I use the term "livewired" to represent that you have billions of neurons reconfiguring their circuitry every second. The connections between them are changing their strength and unplugging and re-plugging in elsewhere.

So this is about more than just changes in nerve connections?

Neuroscientists have focused too much on synapses, like drunks looking for their keys under the streetlight even though that may not be where they dropped them. It's easy to measure synaptic strength. But actually, the brain has many other layers of change which are less easy to study. The inside of a neuron is like a city, and you have all this communication and roadways and infrastructure – all that changes too. Then there are epigenetic changes, which means that in the nucleus of the neuron, the DNA changes shape so that some genes are expressed more while others are suppressed.

Why would the brain need many different mechanisms of plasticity?

I hypothesise that there are different timescales of change. By way of analogy, some things in a city change quickly, like fashions, and other things change more slowly, like which restaurants are in the buildings. Some things are even slower, like the governance, rules and laws. It's similar with the brain. When you learn something new, some parts immediately start adapting, but it's only if what you've learned has relevance and stays consistent that the next layers down say: "OK, that seems like something to hold on to."

How well do we understand these deeper layers?

We have a long way to go. It hasn't been easy to build a theoretical framework to understand › how this happens because, when you look under the hood, what you find in the brain is a system of such complexity that it bankrupts our language. We have no way to understand what 86 billion neurons are doing in there. It's a living fabric, with communities and marriages and divorces.

There are claims that adults have new brain cells developing all the time. Do they play a role in resculpting our brains?

There's controversy about whether this happens at a meaningful level in humans. On balance, it appears that it's a very small feature of neuroplasticity. The thing that is interesting and mysterious is this: if you insert new neurons into a network, how come that doesn't mess it up? If you took an artificial neural network and suddenly inserted new nodes, you'd degrade its performance. Yet somehow that doesn't happen with humans, which just demonstrates that we have a long way to go to understand what's going on in our brains.

Do we see the effects of neuroplasticity in everyday life?

You see it every time you jump on a bicycle or a skateboard. It's as if, instead of being born with two legs, you were born with wheels, and the brain has figured out how to operate its new body. Every time you have to learn something, it is thanks to plastic changes in your brain. When you try a new musical instrument or a new skill, like juggling, we can see changes in the physical structure of your brain. You can tell the difference between, for example, a violinist and a pianist with the naked eye at autopsy or with brain imaging. The violinist is using one hand with great precision and just bowing with the other hand, so only one side of their motor cortex – which is the part of the brain that drives the body – grows larger, in a particular spot that controls the fingers. With a pianist, both the right and the left sides grow.

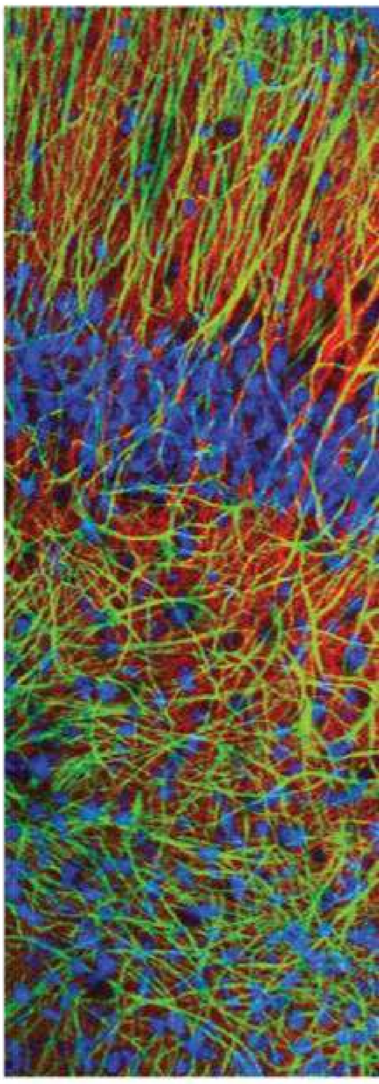
Does neuroplasticity ever put us at a disadvantage?

Mother nature is taking a sort of gamble with humans, in that she drops our brains into the world half-baked and lets experience take over and shape them. Our babies have much less well-developed brains than other animals do at birth. All in all, this has been a successful strategy. We've taken over every corner of the planet, invented the internet – even gotten off the planet, to the moon. But it means that, to develop properly, children require the right sort of input of language and touch and attention and love. In rare cases when a child has been severely neglected, their brains can't do that.

You think there is more we could be doing to make plasticity work to our advantage…

About a decade ago, I got really interested in whether we can create new senses. You have your eyes, ears and nose, but when you look across the animal kingdom, you find animals with detectors that can pick up on things like magnetic fields, electrical fields or ultraviolet light. It just depends what sensors they have. I began to understand our sense organs as "plug and play" detectors. Nature doesn't have to redesign the brain every time she makes a new detector. Instead, she tinkers with different ways of sensing energy. That opens up the idea of creating new kinds of detectors to plug in.

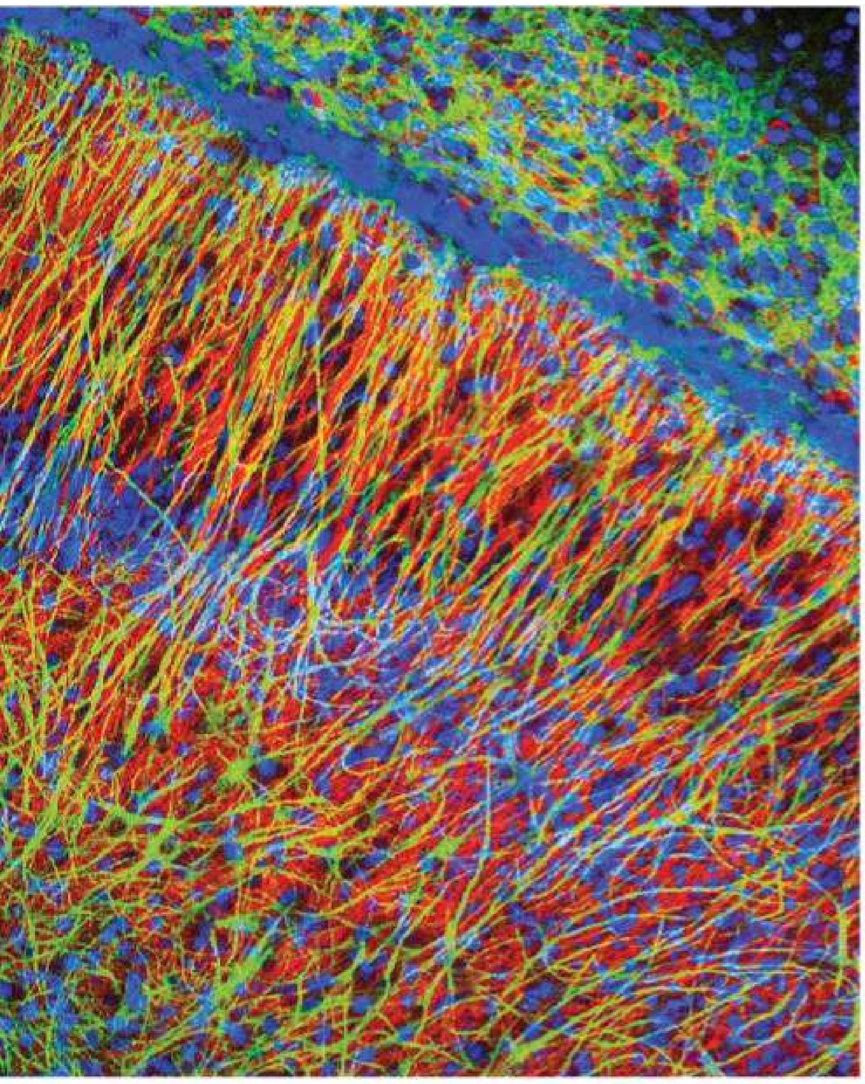
> "What you find in the brain is a system of such complexity that it bankrupts our language"



DR. CHRIS HENSTRIDGE/SCIENCE PHOTO LIBRARY

The Buzz wristband creates patterns of vibration on the skin

NEOSENSORY



Brain cells are constantly reconfiguring their connections

What kinds of new detectors do you have in mind?

My lab began by creating a vest that's covered with vibratory motors. With that, we could translate any kind of data into patterns of vibration on the skin. We more recently shrunk that into a wristband. We can feed in any kind of data, say infrared or ultraviolet light seen by a robot or a drone – or even stock market data. We can also capture information about the state of your body, like your blood pressure and heart rate.

The wristband is now a product called Buzz that captures sound and turns it into patterns of vibration through four motors. That information on the skin follows the nerves up to your brain, which has no problem learning how to come to an understanding of it. Thousands of deaf people are using it. Every day we get emails from people who say they suddenly realised that they left the water running or they can tell the difference between their two dogs barking.

> "I have begun to understand our sense organs as 'plug and play' detectors"

Do you think people will be able to understand speech purely through the device?

Let's take the wristband. The area of skin on which it can create vibrations is pretty small, but even so it can create 4 billion different patterns. If I just hold on to the wristband and say "One, two, three, four", you can clearly feel the difference between all these words. So it's quite high resolution. But the question is: at how high a resolution is your brain reading this information from the skin? People get better and better with time, but what we don't know yet is what the upper limits are. We haven't had somebody wear this for a year yet. I can't wait until we test people who've been wearing this for three years. Because of plasticity, their brains will devote more real estate to understanding the information that comes from the device.

What does it feel like to use?

The first time that you put on Buzz, it just feels like a vibration on your wrist. For example, if you see the dog's mouth moving and you feel the buzzing on your wrist, you suddenly realise: "Oh, I get it, the dog is barking." But over the course of a few months, it becomes like hearing. When we talk to participants about this, we say: "Do you feel a buzzing on your wrist and you think, 'Oh, that must be a dog barking?' " They say: "No, I'm just hearing the dog."

This is exactly how your ears work. When you were an infant, you had to learn how to understand the signals from your inner ears – your brain wasn't born knowing how to do it. When I'm speaking, you don't feel like: "There's some high-frequency sounds, and low frequency and some medium, he must be saying this word." Instead, you just have the experience of hearing. That's what happens with Buzz.

Do you think you could go further with this approach?

Yes. I live in Silicon Valley and everything here is about hardware and software. But what's happening in the brain suggests a completely different approach to building technology – call it live-ware. So I'm interested in building systems that aren't just software but physically reconfigure themselves based on experiences like the brain does. In this way, it would become fast and efficient at the tasks that it does a lot. I feel like we are at the foot of the mountain looking up at it. At the moment, we have no idea how to build this kind of machinery. But I'm excited to see what will happen in the next few decades. ∎

Clare Wilson is a medical reporter for *New Scientist*. Sign up for her weekly newsletter on health and fitness at newscientist.com/sign-up/health

Cranfield University

Study an MSc with a focus on sustainability

Offering postgraduate courses in **Environment and Agrifood, Energy and Power, Water and Design**, Cranfield creates leaders and innovators in sustainability.

- Exclusively postgraduate
- Full and part-time options available
- Exceptional near-industrial scale facilities
- Strong industry links.

To find out more about our courses visit:
E: study@cranfield.ac.uk
T: +44 (0)1234 758082
www.cranfield.ac.uk/studysustainability

Spaces still available for October 2021

GOVERNMENT OF INDIA

Ministry of Education
Department of Higher Education
Technical Section - I

Invitation of Applications for the post of Director, IIT Madras

Applications are invited for appointment to the post of Director of Indian Institute of Technology (IIT) Madras. The Director of an IIT is the academic and administrative head of the Institution. He/she is expected to have a minimum of 5 years' administrative experience and leadership qualities to head an Institute of National importance. The candidate/person should be a Ph.D. with first class or equivalent at the preceding degree, preferably in a branch of Engineering. In exceptional cases, candidates with Science, Mathematics or Management degrees may be considered. He/she should have an outstanding academic record throughout and a minimum of 10 years teaching experience as a Professor in a reputed Engineering or Technology Institute or University and should have guided Ph.D. students. The applicant should preferably be less than 60 years of age on the last date of receipt of the applications. The post carries a fixed pay of Rs. 2,25,000/- (Revised) per month, with allowances as per rules.

2. Interested individuals may apply giving their detailed resume in the prescribed format clearly bringing out research, teaching, industry-academia collaborations and administrative achievements, alongwith a two-page justification in support of their candidature, a two-page vision statement for the institution and contact details of at least two distinguished individuals well acquainted with their work. The application typed in the prescribed format along with enclosures may be sent by Registered/Speed Post to **The Under Secretary (TS.1), Department of Higher Education, Ministry of Education, Room No. 428 "C" Wing, Shastri Bhawan, New Delhi -110 001** so as to reach the Ministry **on or before 31st May, 2021**. The detailed advertisement and the format of application is available on the website (**www.education.gov.in**).

The back pages

Puzzles
Try our crossword, quick quiz and logic puzzle p52

***Almost* the last word**
Why has time never been decimalised? Readers respond p54

Tom Gauld for *New Scientist*
A cartoonist's take on the world p55

Feedback
Martian mushrooms and free pigeon trips: the week in weird p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Stargazing at home

Hunting Leo and Virgo

The moon is a great guide for locating constellations. In May, it will lead us to Leo and Virgo, says **Abigail Beall**

Abigail Beall is a science writer in Leeds, UK. She is the author of *The Art of Urban Astronomy* @abbybeall

What you need

A clear night sky
The naked eye

EARTH, the moon and the other planets in our solar system orbit the sun in roughly the same plane in space. This is because the solar system was made from a spinning cloud of dust that flattened into a disc shape because of its rotational movement. When the planets and moons formed, they remained in this plane, and our flat solar system was born.

What this means for stargazing is that the planets, sun and moon all trace a similar path across the sky. The imaginary line that the sun traces over the course of a year is called the ecliptic.

The ecliptic is also where the zodiacal constellations are found in the night sky. This can be handy because, every so often, planets or the moon will sweep past different constellations, acting as guides to finding them. In May, we can use the moon to point us to two constellations, Leo and Virgo.

On 18 May, the moon will be in its first quarter phase, when it is halfway between a new and a full moon. Wherever you are in the world on this night, it will appear near the constellation of Leo. Just look for the moon when the sun has set and you should be able to find the constellation.

In the northern hemisphere, the moon will appear to be below the Sickle, an asterism (a small pattern or group of stars) that resembles a backwards question mark. In the southern hemisphere, it will look like an upside-down question mark. The Sickle represents the mane of Leo the lion, killed by Heracles in Greek mythology.

BJDLZX/GETTY IMAGES

By the following night, the moon will be firmly within the constellation of Leo, next to the bright star Regulus that marks the bottom of the Sickle. By 20 May, it will be next to the "back" of the lion – if the Sickle makes up the lion's mane – sitting near the star Denebola.

After this, the moon will leave Leo and appear in Virgo, its nearby companion. On 22 and 23 May, the moon will be next to the star Spica, the brightest in Virgo. It will be approaching its full moon phase and getting brighter, so its glare will mean you won't be able to see many stars nearby. However, Spica should be bright enough to still make out.

For the following two days (24/25 May), the moon will travel through Libra. As this is a faint constellation, the moon's glare will probably make it difficult to see any of Libra's stars.

By 26 May, the moon will be full and will have passed through Libra and be next to Antares, the brightest star in Scorpius and 15th brightest in the night sky. If you can't find Antares, use a finger to block out the moonlight and look for the brightest star nearby.

Scorpius is named after the scorpion that, according to Greek mythology, was sent to sting Orion the hunter and prevent him from fulfilling his boast that he would kill every animal on Earth. In the sky, it looks like the constellation is chasing Orion. ▮

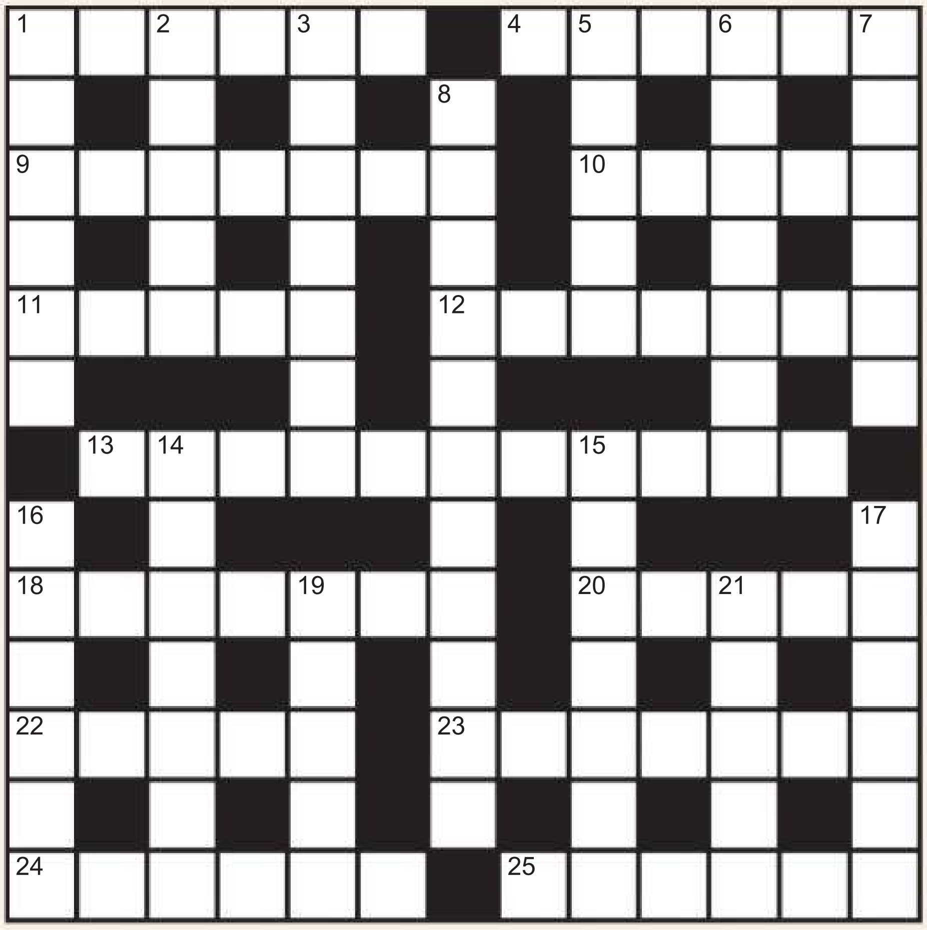
Stargazing at home appears every four weeks

Next week

Citizen science

These articles are posted each week at newscientist.com/maker

Cryptic crossword #57 *Set by Wingding*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Type of whale cooked, stuffed with last of thyme (6)
4 Rival losing his head and vomiting (6)
9 Go after dance album as "something between a pain in the bum and a pain in the neck" (7)
10 Car carrying leader of Belgium, a state of great uncertainty (5)
11 Element of cult radicalised extremist (5)
12 React angrily to hair (7)
13 Surgical procedure repaired empty clones (11)
18 Desire to be in church with Republican group (7)
20 Decline in value of deprived area initially pooh-poohed (5)
22 First woman to have Alzheimer's disease and escape (5)
23 How they cook with pepperoncini, primarily, in part of Italy? (7)
24 Prime number finally made irrational and divisible by two (6)
25 A sin on the same page (6)

DOWN

1 Bird makes sound of two males (6)
2 Own college supporting publicity (5)
3 Beans and cheese Australians might enjoy for starters (7)
5/15 Musk and litigant in a muddle doing several things at once (12)
6 Extremely sleazy politician with cat showing sign of illness (7)
7 Individual gripped by venereal disease under influence of drug (6)
8 Betray the offspring of two hybrids (6,5)
14 Time to lift purple feathers (7)
15 See 5
16 Half of chemists recruited by selenium project (6)
17 Sterilised with blunt instrument to the ear (6)
19 Subject of article on chronic fatigue syndrome (5)
21 Fluid from Mesopotamian city in east (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #101

1 The splitting of a spectral line due to the presence of an electric field is known as what?

2 Which two toad species are native to the UK?

3 Whose observations of the radial velocities of spiral galaxies provided the first empirical evidence that our universe is expanding?

4 Where would you find Alexander's band?

5 How many stages are there in Guedel's classification, a means of assessing the depth of general anaesthesia?

Answers on page 55

Puzzle
set by Zoe Mensch

#113 The two-ewes day paradox

Farmer Giles is thrilled that his rare-breed sheep, Lewecy, is pregnant with twins. He has hired an expert from the genetics clinic to find out more about the lambs-to-be.

The clinic has a reliable prenatal test that looks for fragments of fetal Y chromosome circulating in Lewecy's blood.

The test has come up positive, which means that at least one of the lambs will be male.

"I'm pleased that there'll be another ram on the farm," thinks Giles, "but I do hope the second lamb will be female so that I'll have two ewes on the farm next year. There's roughly a 50-50 split between male and female lambs, so if one's a male then it's odds-on that the other lamb will be female."

Is Giles right to be optimistic?

Answer next week

GALAXY
ON GLASS

SPECTACULAR WALL ART FROM
ASTROPHOTOGRAPHER CHRIS BAKER

Available as Acrylic, Framed & Backlit
or Fine Art Prints. All Limited Edition
www.galaxyonglass.com
chris@galaxyonglass.com +44 (0) 7814 181647

MAY MADNESS
This month there is 15% discount
on all artwork! Simply use the
code MAY at check-out.

redmolotov.com
0121 559 2685
We Do Mugs Too!

Wherever you are, get instant access via the *New Scientist* app

"Easy to use, saves paper, makes my mind dance with ideas."
★★★★★

- The current issue delivered to your device every Thursday
- All past issues going back to 2013
- More than 20 issues of *New Scientist: The Collection* and our new *Essential Guide* series
- Single issue and subscription offers available

New Scientist App

Available on the App Store
GET IT ON Google Play

★★★★★ 4.6

On time

Since I was a child, most measurements have been decimalised. Why not time?

Roger Lampert
St Albans, Hertfordshire, UK
It is probably for the same reason that there aren't 100 degrees in a circle.

Stephen Johnson
Eugene, Oregon, US
If you go far enough back in human history, time was divided into only two components: day and night. The first attempts to measure time more accurately were concerned with measuring and dividing the hours of daylight, using a sundial and, later, sand and water clocks.

The division of the day into 24 equal parts comes from the Egyptians. They broke the daylight hours into 10 sections, and added a "twilight" hour for the morning and evening. The Egyptians used a sexagesimal system, with a base of 60. This system, which was also used by the Babylonians, divided both the circle and the year into 360 segments. Our 24 hours in a day, 60 minutes in a hour and 60 seconds in a minute all derive from this.

> "The best chance for decimal time to take hold may be on another planet, on a long-duration Mars mission"

It is worth noting that, in addition to time, many things aren't measured in units of 10. In the US, the foot, the mile and the 64th of an inch are very much alive.

BORIS SV/GETTY IMAGES

If the universe is expanding, are objects and atoms doing so too?

This week's new questions

Expansive objects **Physics tells us the universe is expanding in all directions. Does this include atoms and objects, such as me?** ***James Fenton****, Clachan Seil, Argyll and Bute, UK*

Antarctic bears **The Arctic ice is disappearing, so could polar bears be established in Antarctica to save the species?** ***John Kendall****, Letchworth, Hertfordshire, UK*

Chris Warman
Hinderwell, North Yorkshire, UK
Decimal time, while not in general use, still ticks over in scientific applications. And until 1645, China had a decimal time system that went back millennia. Once the Jesuits brought Western time to the country, China adopted the system.

The most famous experiment in decimal timekeeping occurred in France in the 1790s, along with the introduction of metric weights and measures. The day, from midnight to midnight, was divided into 10 hours of 100 minutes, each further divided into 100 seconds. They didn't quite manage to decimalise the year, which still consisted of 12 months. These were each 30 days long, with three 10-day weeks.

This ceased to be mandatory in 1795, but metrication survived and spread because a logical, standardised system was more useful than a hotchpotch of localised weights and measures.

At the moment, it seems unlikely that decimal time will come into general use. Too much is invested in the standard system and it is too intimate a part of everyday life. From working in retail at the time of decimalised currency and of metrication, I know just how much the public resents change.

Bill Hay
Lacey, Washington, US
When I was a student at the University of Edinburgh back in the 1960s, our professor of mathematics, Alexander Aitken, was a strong advocate for changing our entire counting system to be duodecimal (base 12).

The benefit of this is that 12, in mathematical terms, is a "superior highly composite number", as is 60. Poor 24 is merely a "highly composite number", but this still means that, unlike 10, it has more divisors than any other smaller number. This makes it easy to talk in common fractions. The unit 20 minutes is one third of an hour, much easier to think about than 33.333 decminutes, or whatever we would call them.

Garry Trethewey
Cherryville, South Australia
Social inertia makes it hard to replace one system with another. Take the QWERTY keyboard, which is clumsy, slow and should be replaced with the Dvorak keyboard, which was designed for maximum typing efficiency.

Of course, a base-16 system is even more sensible than a decimal (base 10) system, but that will never be introduced.

Chris Knight
Toronto, Canada
Old habits die hard: look at the grip of imperial measurements on the US, which shrugged off most other British institutions centuries ago.

The best chance for decimal time to take hold may be on another planet. Scientists currently calculate Martian time for land-based rovers, such as Perseverance, by determining the local noon and then stretching each second by a tiny fraction.

This means that a Martian day (or sol), which lasts about 24 hours and 39 minutes in Earth time, instead lasts exactly 24 slightly stretched hours in Martian time. Confusingly, the rovers themselves keep time in Earth seconds, which are then converted to Martian time as needed.

This kind of calculation will be impractical for future humans on long-duration Mars missions. They will either need to adopt longer seconds, or else come up with new units, perhaps on a base-10 system, and preferably with far-out Martian names for each hour.

Want to send us a question or answer?
Email us at lastword@newscientist.com
Questions should be about everyday science phenomena
Full terms and conditions at newscientist.com/lw-terms

Tom Gauld

for New Scientist

NOTHING'S HAPPENING.
LET'S TAKE A WALK.
WE CAN'T RUN THIS EXPERIMENT FOREVER.
YOU SAID THAT LAST TIME.
LET'S GIVE IT ANOTHER TRY, I'VE GOT A GOOD FEELING.
BUT HOW LONG DO WE WAIT?
GOOD THINGS COME TO THOSE WHO WAIT.

Carrying weight

I recently lost 15 kilograms, so why can't I comfortably pick up and carry a 15kg weight? I was fine carrying this weight when it was distributed all over my body.

Martin Jenkins
London, UK
In 1916, British troops marched to the Battle of the Somme wearing packs that weighed about 30 kilograms. This is roughly the same as a 16th-century knight's plate armour. However, this armour covered the whole body and was designed to be flexible, so knights were able to walk and mount their horses. The soldiers had to load all the weight on their backs and were exhausted on arrival.

It isn't how much you are carrying but how and where you carry it that makes the difference.

Nick Baker
Colchester, Essex, UK
Our skeletal geometry and muscular system has evolved to cope with our own body weight when sitting, standing and walking. Excess body weight tends to be added to specific areas, such as the trunk, waist and upper limbs, which are already the more massive parts of the body.

> **"A 16th-century knight in heavy plate armour could still walk and mount horses. The distribution of the weight is key"**

"Coping", in this sense, means supporting the weight with a minimum expenditure of energy. This is achieved mainly by posture, so that stresses on the body are predominantly compressive and hence transmitted to the rigid bone of the skeleton, requiring only minimal muscular action to maintain balance.

In order to carry a weight, however, particularly when concentrated in a single, dense object, large tensile forces are involved. Muscles provide these forces – the biceps, for example, when carrying a pile of books – but they eventually become fatigued and indicate this through feelings of discomfort and pain.

If the extra weight can be carried in such a way as to increase only the compressive forces taken by the skeleton (the spine and the legs), then less fatigue and discomfort results. This, together with an upright posture, explains how some people can carry huge loads on their heads.

The closest most of us get to this is wearing a well-designed rucksack, but even that requires a (less elegant) change of posture to bring the centre of mass of the ensemble above the feet.

Chris Warman
Hinderwell, North Yorkshire, UK
If the correspondent had lost 15 kilograms rapidly, this would lead to muscle being lost at a faster rate compared with longer-term dieting. Under severe calorie restriction, the body uses glycogen from the muscles and liver to provide the energy to stay alive, making it weaker. ▮

Answers

Quick quiz #101
Answers

1 The Stark effect
2 Common toad (*Bufo bufo*) and natterjack toad (*Epidalea calamita*)
3 Vesto Slipher
4 Between rainbows – it is the dark area between double rainbows
5 Four: disorientation, delirium, surgical and overdose

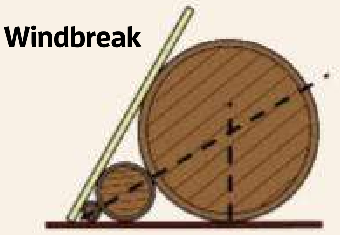
Quick crossword #82
Answers

ACROSS 1 Hovered, **5** Lycopod, **8** Aphid, **9** Occlusion, **11** Microwave oven, **13** Prefab, **16** Cortisol, **18** Listeria, **24** Heath Robinson, **26/19** Three Mile Island, **27** Fungi, **28** Maxwell, **29** Starchy
DOWN 1 Heat map, **2** Vehicle, **3** Radio, **4** Deodar, **5** Locked on, **6** Prion, **7** Donor, **10** Up-votes, **12** Moon, **14** Rail, **15** Average, **17** Fish kill, **20** Arsenic, **21** Density, **22** Bowels, **23** Datum, **24** Hyrax, **25** Infra

---

#112 A muse in the barrel
Solution

The third barrel has a diameter of 180 cm. The angle between the ground and the line passing through the centre of the barrels is 30 degrees, so in the dotted triangle, the height divided by the hypotenuse = ½. The smallest barrel's radius is 10 cm, so if the second barrel has radius a and the third b, a/(a+30) = ½, so a = 30, and b/(b+90) = ½, so b = 90 and the third barrel's diameter is 180 cm.



Space oddity

In terms of big science news, this is up there with the biggest: there is life on Mars!

The internet was abuzz last week when news emerged that mushrooms had been spotted on the Red Planet. The fungal life forms had been seen in photos taken by NASA rovers nearly two decades ago, and somehow overlooked by the space agency for all these years.

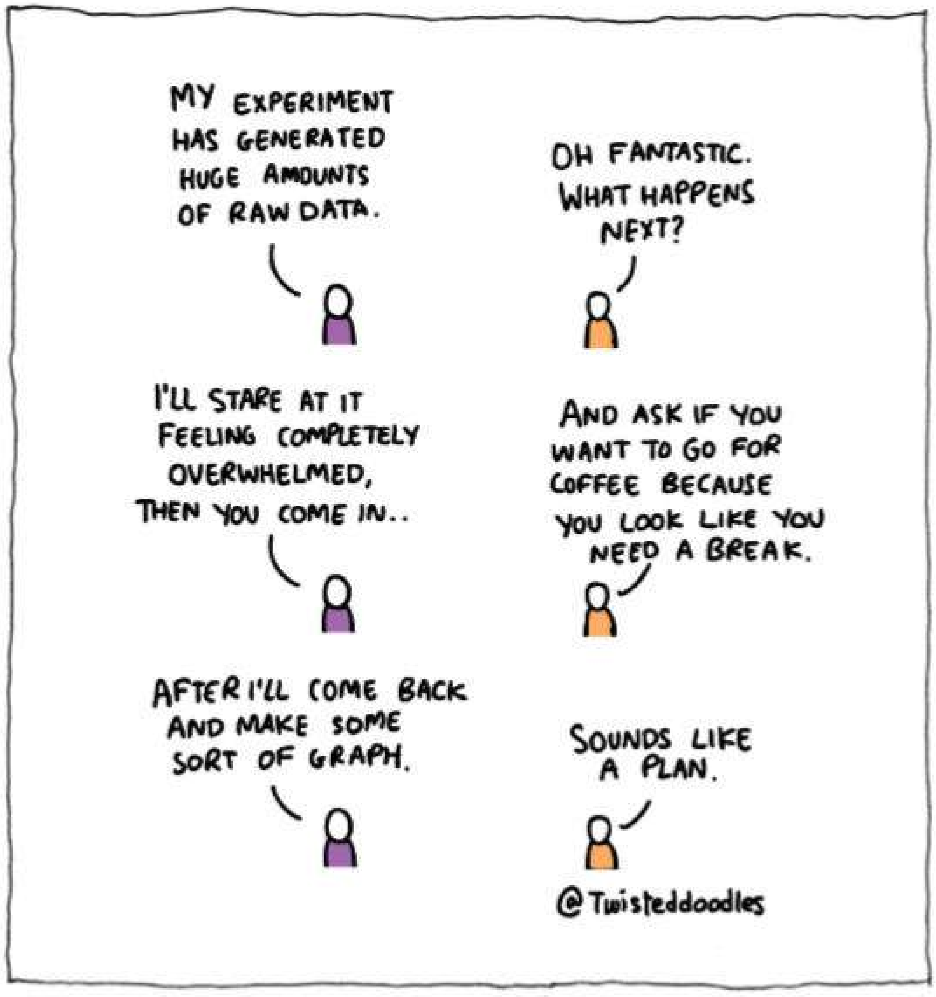
The paper making this claim, published online by the journal *Advances in Microbiology*, asserted that the photos showed spherical "mushroom-like" formations, which even expanded in diameter over sequential photos, suggesting biological growth. The authors said that NASA had ignored other evidence of life on Mars in the past due to peer pressure.

The paper has had a mixed reception, it is fair to say. While some online news sites lapped it up, others were more sceptical. To get to the bottom of things, Feedback tried to consult *New Scientist*'s space correspondent, but she seemed reticent, claiming to be busy working on "real stories".

When finally pinned down, our reporter said that NASA had already investigated the strange formations, and concluded they were spherical, iron-based rocks half buried in sand, nicknamed blueberries. The most likely explanation for their increase in size was that wind had blown away some of the sand.

"These are known phenomena," she sighed. "If there were life on Mars, every scientist who studies Mars would be out of their mind with joy – they would not try to keep it secret."

Twisteddoodles *for New Scientist*


MY EXPERIMENT HAS GENERATED HUGE AMOUNTS OF RAW DATA.
OH FANTASTIC. WHAT HAPPENS NEXT?
I'LL STARE AT IT FEELING COMPLETELY OVERWHELMED, THEN YOU COME IN..
AND ASK IF YOU WANT TO GO FOR COFFEE BECAUSE YOU LOOK LIKE YOU NEED A BREAK.
AFTER I'LL COME BACK AND MAKE SOME SORT OF GRAPH.
SOUNDS LIKE A PLAN.
@Twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com or
New Scientist, 25 Bedford Street, London WC2E 9ES
Consideration of items sent in the post will be delayed

China crisis

One of those so-called "real stories" taking up the time of our space correspondent was no doubt the fate of a China National Space Administration (CNSA) Long March 5B rocket, which took off last month to deliver a living quarters module for the nation's upcoming space station.

What goes up must come down, however, and last week the remains of the rocket performed an "uncontrolled re-entry" – which, in layperson's terms, means simply letting it fall back to Earth as gravity sees fit, and hoping it doesn't hit anything.

Thankfully, that's exactly what happened. The rocket remnants splash-landed in the Indian Ocean last Sunday – unlike last year, when debris from a previous CNSA rocket crashed onto two villages in the Ivory Coast.

On that occasion, no one was hurt, but some buildings didn't come out of the encounter so well. China plans another 10 rocket launches to complete its space station, so perhaps we should still keep our fingers crossed – and our building insurance up to date.

Politicians tried to express their views about such a que sera sera approach to rocket safety without causing a diplomatic incident. "For those of us who operate in the space domain, there's a requirement, or should be a requirement to operate in a safe and thoughtful mode," US defense secretary Lloyd Austin was quoted as saying in *The Guardian*.

But eagle-eyed *New Scientist* reader Marc Smith-Evans in Nueva Vizcaya, the Philippines, spotted something more notable in that same article.

It predicted that the debris would land "between Saturday and Sunday", which left Marc scratching his head about how such a time period could be compatible with our current understanding of science. He concludes: "This isn't time travel but something far more impressive."

Birdbrained

Perhaps China's space agency shouldn't be judged too harshly for failing to control where its rocket debris lands, as the field is famously difficult. We don't have the saying "it's not rocket science" for nothing. For instance, when Skylab, the first US space station, came down from orbit in 1979, NASA failed in its attempt to steer it into the ocean and ended up smearing it across Western Australia.

Again, no one was hurt. But a municipality called the Shire of Esperance on Australia's south coast, which copped some of the debris, issued NASA with a AUS $400 fine for littering. This went unpaid until 2009, when a Californian radio DJ raised the funds from listeners as a publicity stunt.

In a not-at-all tenuous link, another challenge of a similar difficulty to controlling de-orbiting rocketry is the question of how to curb numbers of feral pigeons in town centres. Don't scoff: pigeons can cake buildings in guano and spread diseases, but many high-tech deterrents don't actually work and culls tend to trigger outrage among animal lovers.

Now, councillors in Hungerford, a market town in the south of England, have had a different idea: humanely trapping the birds and releasing them more than 400 kilometres away, at the seaside town of Whitby in North Yorkshire.

What the plan's originator has against Whitby is unclear. And how would the town's residents feel about it, wonders reader Liz Bell. Would they retaliate by dispatching their own unwanted pigeons to Hungerford, or might the original pigeons take matters into their own wings and return? They are known for their homing abilities, after all.

But Hungerford deputy mayor Keith Knight told the *Newbury Weekly News* that the town had run out of other options. "We've tried alternatives without making progress," he said. "We're going round in circles." Rather like the pigeons might. ▮

NewScientist
ESSENTIAL GUIDES

SUBSCRIBE FOR
ONLY £49.99 A YEAR

NEW SCIENTIST ESSENTIAL GUIDES

DELIVERED DIRECT TO YOUR DOOR

Based on the best coverage from *New Scientist*, the *Essential Guides* are comprehensive, need-to-know compendiums covering the most exciting themes in science and technology today.

Get the series, including the brand new issue on Evolution, with an *Essential Guides* subscription. It means you don't have to search for issues in the shops – we can deliver them direct to your door.

FOR MORE INFORMATION ON FUTURE ISSUES AND SUBSCRIPTION OFFERS, VISIT:

NEWSCIENTIST.COM/ESSENTIALGUIDE

Shop at omegawatches.com

WORLDTIMER GMT

Since 1848, OMEGA has timed historic events and human achievements around the world. The Worldtimer embodies that pioneering spirit with a dial that provides an accurate view of the world's time zones with just a glance. Continuing that commitment, today's Master Chronometer models are tested and certified at the highest level by the Swiss Federal Institute of Metrology (METAS). This guarantees more accuracy, reliability and supreme resistance to magnetism from electronic devices, such as phones and laptops, ensuring the Worldtimer is always adventure-ready.

Ω
OMEGA